Under-Ventilated Compartment Fires – A Precursor to Smoke Explosions

A report submitted in partial fulfilment of the requirements for the degree of Master of Engineering in Fire Engineering at the University of Canterbury, Christchurch, New Zealand.

by

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Abstract

Fourteen experiments were conducted at the University of Canterbury using a 1.0m x 1.0m x 1.5m compartment with liquid pool fires. They were conducted to experimentally study, in reduced scale, the conditions that exist in under-ventilated compartments, with a focus on smoke explosions. Ventilation into the compartment was controlled to force the fire to burn to extinction, with the temperatures and fuel mass loss rates being recorded.

In the process of determining these conditions, the behavioural properties of various building materials and their limitations showed testament to the difficulties that arise when attempting to control a natural energy. Trying to build a compartment to contain fires of temperatures up to 1100°C, was in itself a testing process. The initial fire resistant building materials used, were found to have adverse effects when repeatedly exposed to fires.

Although a smoke explosion was not produced, steady state mass loss values for various ventilation openings were found. These were then used to produce a very good ventilation dependent mass loss trend line. The point of extinction of these fires was found, which will be of use in further research.

The fires conducted in the experiments were supplied with minimal oxygen, and all produced excessive quantities of unburnt fuel. This was due to the generation of pyrolyzates as a result of the radiative feedback off the compartment walls, diffusion flame and gas layer. The fire initially burns in the pan, until all oxygen within the compartment has been depleted. At this point the combustion transfers from inside the pan, to burn in the localised vicinity around the pan where oxygen is able to penetrate. The combustion then progresses through a transition stage, in which the flame front moves from the rear of the compartment, to the front. This involves a period where the flames oscillates backwards and forwards from the vent. Steady state burning occurs continuously within the vent. Once steady state burning in the vent is achieved, no

degree of ventilation reduction, except full sealed closure, would result in extinction of the fire. A fire occurring at this stage is fully fuelled from the volatilisation of the liquid pool at the rear of the compartment. The mass loss of fuel due to this type of burning is found to be well in excess of that available to ventilation controlled stoichiometric burning. The neutral plane layer was found to be located at approximately the mid-height of the opening and little effect is seen on the location of the neutral plane layer at these low ventilation limits.

Acknowledgments

Firstly I would like to thank Dr Andy Buchanan for creating such a worthwhile course that was needed, and also for his support and encouragement throughout the year. Thanks also goes to the New Zealand Fire Service for their funding and assistance with the course, as without their support it would not exist.

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Finally, thanks to my Mum and Dad who have supported me throughout my education. For without you I would not have been able to do the things I have done in the last 5 years. It's been a hard, but worthwhile slog. With this report I now set you free. Also thanks to my brother and sister. Living at opposite ends of the country you miss out on a lot.

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Nomenclature

a	=	smallest dimension(m)
A	=	area (m^2)
b	=	largest dimension (m)
c	=	plate bending coefficients
C	=	fuel characteristic coefficient ($Pa^{½}$)
h	=	height (m)
k	=	extinction-absorption coefficient of the flame
l	=	simply supported span length (m)
$\dot{m}$	=	mass flow rate (kg/s)
$\dot{m}''_{\infty}$	=	mass loss rate for an infinite diameter pool (kg/m^2 s)
P	=	failure load (N)
P_{red}	=	resistant design pressure (Pa)
P_v	=	static vent opening pressure (Pa)
r	=	stoichiometric air/mass ratio
W	=	width (m)
t	=	glass thickness
T	=	temperature (K)
TC	=	thermocouple
z	=	height above floor (m)
Z	=	section modulus (m^3)

Greek Symbols

σ	=	Stefan-Boltzmann constant (W m^{-2} K^{-4})
σ_f	=	failure stress (Pa)
β	=	mean-beam-length corrector
Δh_p	=	heat of gasification (J kg^{-1})

Subscripts

b	=	boiling point
d	=	door/ventilation opening
db	=	bottom of ventilation opening
dt	=	top of ventilation opening
f	=	fire
g	=	glass
i	=	inside compartment / inflow

max	=	maximum
n	=	neutral plane
o	=	outflow
p	=	pool
r	=	accumulated inside compartment
s	=	internal surface
v	=	vent / fuel volitiles
x	=	x, short dimension
y	=	y, long dimension
∞	=	ambient

Chapter 1. Introduction

No fire ever behaves exactly the same. There is an increasing number of variations, which are brought to our attention as the understanding of its complexities increases. Full scale studies, which even include accidental fires, whether they be in a natural or man made environment, have shown a need to further the study into these complexities and dynamics. Therefore the study of fire phenomena in reduced scale, has been used to pursue the understanding of fire through expedience and ease. Many of the things that occur in our natural surroundings are precluded by experimental study before the more complex mathematical solutions arise.

The study of the behaviour of fires is important in terms of people safety. Not only are the public in danger in fires, but also the firefighters that risk their lives to save people and property. People die in fires in buildings because they are unable to reach a place of safety, due to the untenable conditions. Burning rates of objects on fire change the safe egress times that escaping people have to travel. Radiative heat flux from these fires, in the form of flames and the hot gas layer, to surrounding objects determine the possibility of ignition, flame spread and flashover. These also determine the rate at which untenability is reached and the effects that the fire has upon construction elements.

The aim of this project was to experimentally study, in reduced scale, the conditions that exist in under-ventilated compartments with a focus on smoke explosions. This new unstudied phenomenon has been previously witness in backdraft studies and in other experiments conducted at the University of Canterbury.
Unlike a backdraft where the fire occurs in a fully closed compartment, with the resulting deflagration occurring from the introduction of a gravity current, these smoke explosions occur in closed compartments where the fire is under-ventilated. Due to the condition of under-ventilation, combustion takes place producing large amounts of smoke that contain a high fraction of unburnt fuel. If the conditions within the

compartment are right, this unburnt fuel or pyrolyzates, can ignite and result in a low level explosion. It is therefore important to try and determine the effects that a smoke explosion may have upon people at risk.

Experiments were conducted at the University of Canterbury using a 1.0m x 1.0m x 1.5m compartment with liquid pool fires. Ventilation into the compartment was controlled to force the fire to burn to extinction, and the results of these analysed.

Chapter 2. Compartment Chronology

2.1 THE EXPERIMENTAL COMPARTMENT.

The original compartment which is shown in the photo in figure 2.1, was constructed by technician Ray Allen for fire purposes in 1994. It consisted of a 50 x 50 x 5 mm angle iron frame on to which were fixed one layer of 20 mm Gib® Fyreline and two layers of PROMATECT® H which is a calcium silicate board. These were the exterior and interior linings respectively. A cross-section through the compartment showing the wall layout can be seen in figure 2.2.

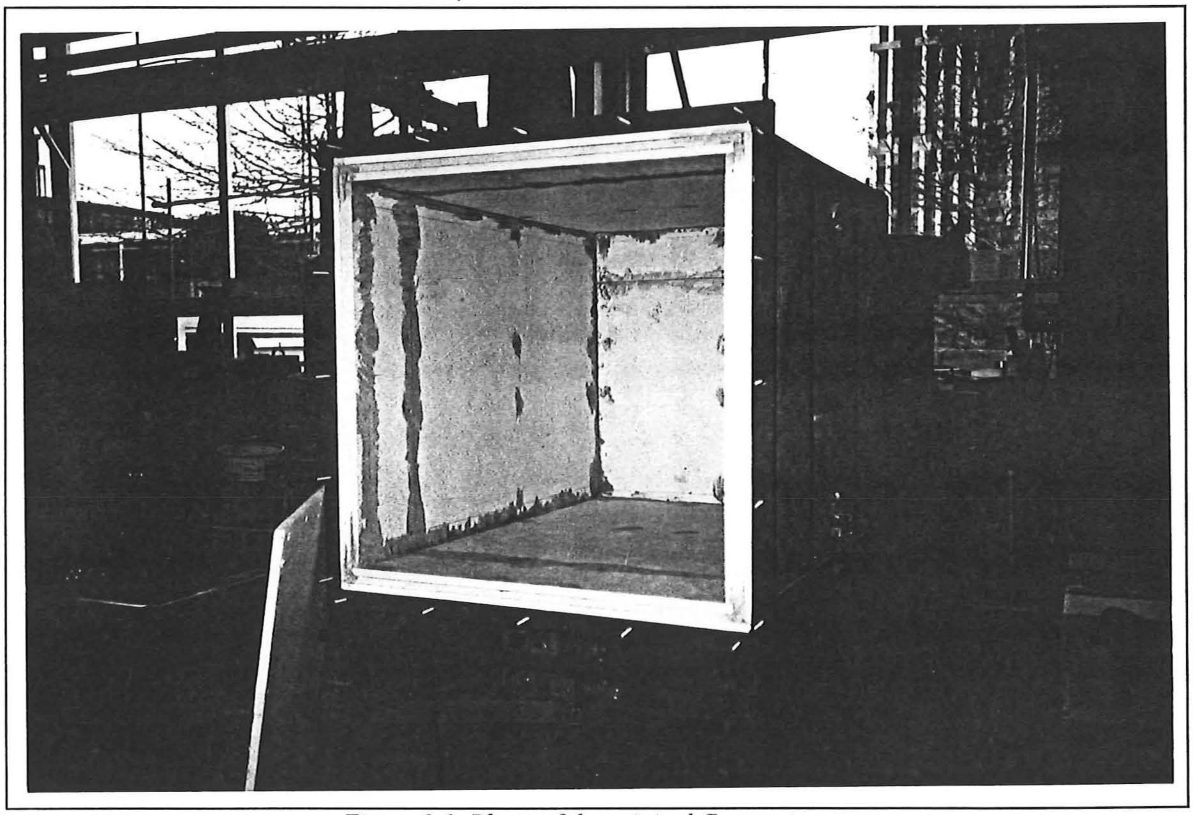

Figure 2.1 Photo of the original Compartment.

The second interior lining of PROMATECT® H was fixed to the Gib® by bolts. The first and inside lining layer of PROMATECT® H was screwed to the second layer (see Figure

2.2). This was done to minimise the effect of the conduction of heat through to the exterior layer of Gib® Fyreline.

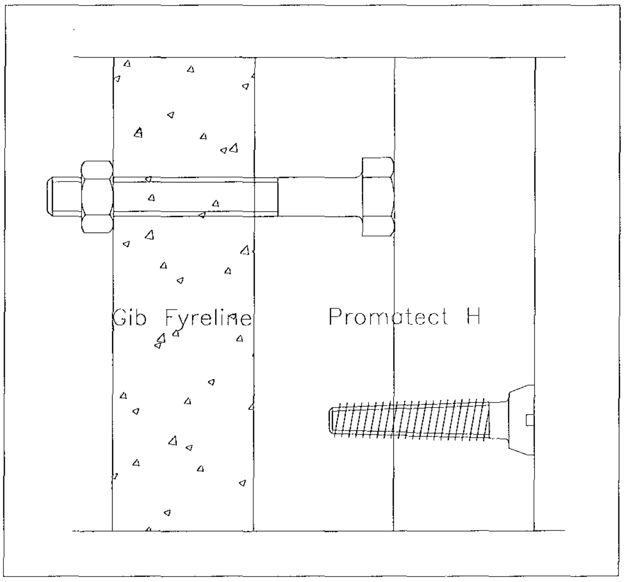

Figure 2.2 Cross-section through the compartment wall

All joints, and bolt and screw heads, were filled with Promat K 84 fire resistant cement. The initial internal dimensions of the compartment were 1.0 m x 1.0 m x 1.5 m long.

The compartment rests on a 0.8 m high movable frame also constructed of 50 mm angle iron. The drawing in Figure 2.3, shows the original compartment sitting on the base frame. 50 mm flat vertical bracing members were located at each third point along the compartment and also at the midway point on the back wall (see Figure 2.3). Locater plates were used to keep the compartment firmly on the base and a hand rail out the front was used to move the base and compartment around. Connected to the frame are four leveling feet, so that the compartment can be levelled and the pan containing the liquid fuel is also level.

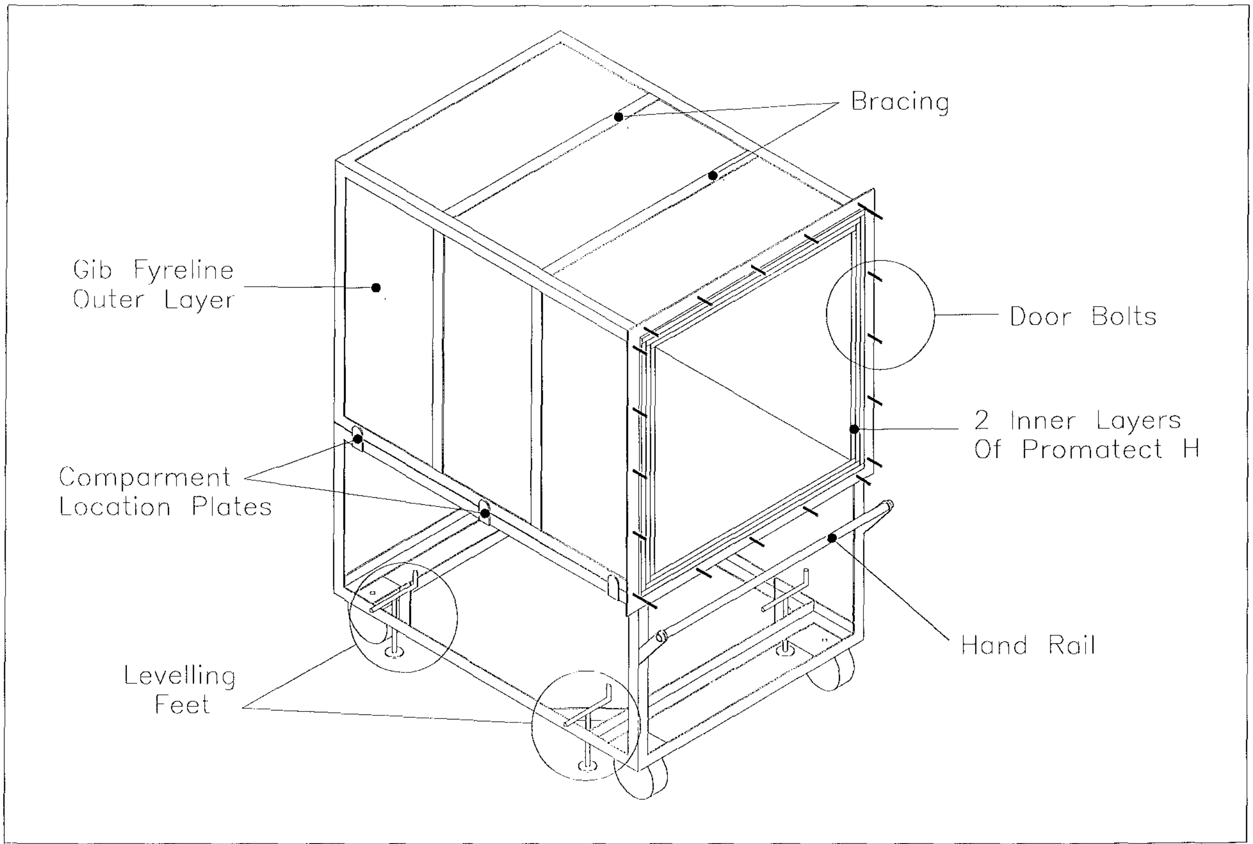

Figure 2.3 Drawing of the original compartment and base unit.

The door of the container was constructed of one layer of PROMATECT® H board reinforced around the edges by 50 mm flat. It was held to the compartment by 20 bolts and wing nuts.

Modifications were made to the container so that it could be used for variable ventilation, for increased pressure environments, and for use with liquid fuels. Additions were also made for instrumentation and data acquisition purposes.

This involved the inclusion of a pressure relieving venting panel in the floor, and angle iron runners and panels either side of the fixed opening to vary the ventilation.

2.2 WINDOW.

It was envisioned that a small window would be placed into the side of the compartment to observe the behaviour of the fires within. FireLite fire rated glass from Technical Glass Products, and manufactured by Nippon Electric Glass Company Ltd was to be used. However, due to time restrictions this was not incorporated. The analysis carried out on samples of glass provided was critical in designing the pressure relieving panel (see section 2.3.1).

2.3 EXPLOSION PROTECTION.

Pool fires produce gases and vapours that can be highly flammable. These flammable gases and vapours present a hazard if mixed with air in proportions between the lower and upper flammability limits (1.10%- 6.7% respectively for Heptane, [1]). If they ignite, an explosion can result, called a deflagration. Deflagrations are the propagation of the combustion zone at a velocity less than the speed of sound away from the source into the un-reacted zone. This releases a rapid amount of energy, the expansion of gases and the development of overpressures within the compartment. Therefore, due to the nature of the research in determining the occurrence of smoke explosions, the compartment had to be protected against a sudden increase in pressure.
In a deflagration the pressure front reaches the venting panel before the flame front. As such, the most effective venting systems are those that open early in the deflagration and have as large an unrestricted venting area as possible.

The deflagration force was restricted to the downward direction to keep full structural integrity in the walls and roof. Therefore this involved the design of a pressure relieving venting panel that was to be located in the floor. This panel is intended to vent the force quickly and safely before it causes excessive damage to the compartment.

The design of a pressure venting panel depends upon the strength of the compartment elements, rate of pressure rise, the maximum pressure developed for the fuel mixture and the weight and location of the release panel.

The limiting factor in the design of the pressure relieving panel is the strength of the weakest resistant element (P_{red}). Therefore analysis was carried out on the following elements of the compartment.

2.3.1 Window

Two FireLite fire rated glass specimens were provided. A standard (non-polished surface) and premium (polished surface) specimen, both with dimensions of 148 mm x 89 mm x 5 mm. These were analysed as the size of window to be fitted into the compartment. A simply supported test was carried out on the samples of glass provided using an Instron test machine, with a simply supported span of 120 mm.
Both of the specimens failed at 1.4 kN.

The FireLite fire rated glass specification sheet, (see Appendix A2), gave an average bending strength of 69.7 Mpa (710.0 Kg/cm^2). The corresponding failure load was then calculated from :

$$M = \sigma_f . Z \qquad \text{...(2.1)}$$

Where: M = bending moment (kNm)

σ_f = failure stress (MPa)

Z = section modulus (m^3)

$$Z = \frac{W_g . t^2}{6} \qquad \text{...(2.2)}$$

W_g = glass width (m)

t = glass thickness (m)

and

$$P = \frac{4M}{l} \qquad \text{..(2.3)}$$

Where: l = simply supported span length (m)

The failure load was found to be 0.86 KN.

Therefore the smallest value of 69.7 MPa was applied as the limiting bending strength. This was then used to determine the maximum pressure allowable under plate bending analysis. The bending strength per metre width was needed, and corresponded to 0.290 kNm/m width.

Assuming that when installed the window would be simply supported on all four edges, plate bending formulae by Szilard [2] were used to calculate the maximum pressure allowable. These had the following form

$$M_{x\max} = c_2 P\, a^2 \qquad \text{.......................................(2.4)}$$

$$M_{y\max} = c_3 P\, a^2 \qquad \text{.......................................(2.5)}$$

Where c_2 and c_3 are factors dependent on the ratio of the plate dimensions $^b/_a$, where b is the largest dimension. As $^b/_a$ is equal to 1.66, interpolation of the plate bending table in Szilard [2], gave the corresponding limiting factor to be c_2, with a value of 0.0890. From Equation (2.4), it was then found that the glass could withstand a maximum pressure of 412 kPa.

2.3.2 Compartment Strength

The walls, floor and roof of the compartment all consist of three layers of PROMATECT® H. Therefore, the compartment door was judged to have the weakest strength characteristics, as it consisted of only one layer of PROMATECT® H board. It also had a hole located in its centre, which would reduce its strength.

The properties of PROMATECT® H obtained from the specification sheet (see Appendix A1) show that it is anisotropic. This can be seen by the stronger tensile and flexural strength affinity the board has in the longitudinal direction. As such, plate bending structural analysis similar to the above was conducted with reference to the boards weakest plane.

As the size of the fixed ventilation opening in compartment door had not been decided numerous different combinations were analysed. These results were then used to determine the maximum allowable pressure.

It was decided that a 500 mm x 500 mm hole would be cut in the door. This gave a corresponding limiting pressure of 54.5 kPa.

The limiting pressure calculated from the compartment door was found to be less than that obtained from the glass analysis. Therefore it was used as the maximum resistant design pressure for the design of a low strength enclosure.

2.3.3 Pressure Venting Panel Design

The pressure relieving panel should be able to be released at the lowest possible pressure. "Generally, a static design pressure of 0.96 kPa is sufficient and is preferred. The design pressure for pressure-relieving walls should in no case exceed 1.92 kPa" [3]. Due to the strength of the compartment elements, the vent panel could have been designed to the specifications of a high strength enclosure. However, it was decided to keep the maximum overpressures to a minimum and design for a low pressure enclosure where the resistant design pressure (P_{red}) does not exceed 10 kPa.

To be able to design for as large as relieving pressure as possible, the upper limit of 1.92 kPa for low pressure compartments was used to determine the size of the pressure relief panel.

The general form of the venting equation is

$$A_V = \frac{C \quad A_S}{\sqrt{P_{red}}} \qquad \text{..................................(2.6) [4]}$$

Where: A_v = vent area (m^2)

C = fuel characteristic constant ($kPa^{1/2}$)

A_s = Internal surface area of the enclosure (m^2)

P_{red} = resistant-design pressure (kPa)

Table 2.1 [3], was then used to calculate the surface to vent area ratio. As the limiting resistant-design pressure calculated from the compartment strength was greater than provided in the table, the maximum of 10.32 kPa was used. Using 1.92 kPa as the static vent opening pressure, the corresponding surface to vent area ratio was 12.

Table 2.1 Surface to Vent Area Table, [3]

P_v	A_s/A_v																		
	3*	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
0.96*	3.60	3.60	4.03	4.42	4.80	5.23	5.62	6.00	6.43	6.82	7.20	7.58	7.97	8.30	8.69	9.12	9.55	9.94	10.32
1.20	3.60	3.60	4.03	4.42	4.80	5.23	5.62	6.00	6.43	6.82	7.20	7.58	7.97	8.30	8.69	9.12	9.55	9.94	10.32
1.44	3.84	3.84	4.03	4.42	4.80	5.23	5.62	6.00	6.43	6.82	7.20	7.58	7.97	8.30	8.69	9.12	9.55	9.94	10.32
1.68	4.08	4.08	4.08	4.42	4.80	5.23	5.62	6.00	6.43	6.82	7.20	7.58	7.97	8.30	8.69	9.12	9.55	9.94	10.32
1.92	4.32	4.32	4.32	4.42	4.80	5.23	5.62	6.00	6.43	6.82	7.20	7.58	7.97	8.30	8.69	9.12	9.55	9.94	10.32

The internal surface area of the enclosure is 8 m, which gives a resulting required vent area of 0.667 m^2.

A panel was then cut into the floor of the compartment of dimensions 855 wide by 780 mm long. The floor of the compartment also consisted of the same three layers as the walls. Therefore the venting panel was designed to utilise these three layers. Figure 2.4 shows a cross-section through the venting panel layers. The first layer was cut to the venting panel dimension, with the following layers being tiered (see Figure 2.4). Plywood was substituted for the last layer to add support to the door and hinges.

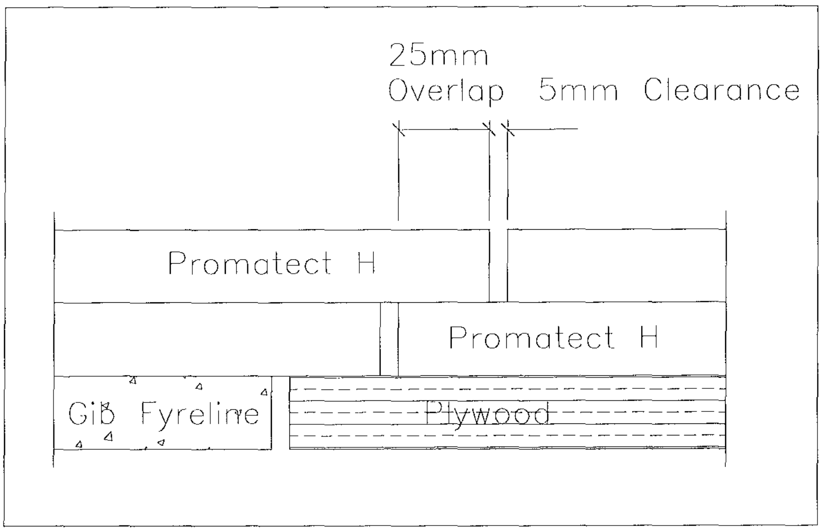

Figure 2.4 Tiered layering system of explosion panel.

This was to provide an adequate seal so that no gases or flames could escape through the vent. A 5 mm clearance gap was allowed, so there were no restrictions on the opening of the venting panel.

The weight of venting panels should be kept to a minimum, as the opening acceleration is inversely proportional to its mass. As the venting panel within this compartment is subjected to continuous fires, it needed to be fire resistant. This fire resistance adds weight greater than preferred, but in no circumstances should the panel weight exceed 40 kg/m^2 [3]. The total weight of the panel was kept to approximately 30 kg/m^2. The three layers were fastened together by bolts, which were covered with a heat resistant cement. The bottom of the door was reinforced by 50 mm flat around the edges to give some structural support.

2.3.3 Venting Panel Fastener/devices and calibration

The venting panel was then fixed to the bottom of the compartment by two hinges. These hinges were connected to the steel frame of the base unit and to the steel support surrounding the door. Two lengths of 30 mm angle iron were welded to the base frame at an angle of 40-45°. This was the support on which the venting panel would land when activated. Sheet steel was then fixed on all sides of this frame so that flame and combustion gases could be discharged and ducted directly into a safe location. Two rubber pads were made up, and attached to the frame to act as shock absorbers for the door.

Although the weight of the venting panel was kept to a minimum, it was still considerably heavy. A conventional adjustable ball lock was trialed, but did not have enough force to hold the door shut. Therefore a strong adjustable spring ball lock was made to take the weight of the door. This was attached to the door along with a similarly made female end.

To calibrate the lock and subsequently the venting panel, a polythene bag was made to dimensions greater than that of the compartment. A pressure transducer was place within the bag, which was then inflated inside the compartment with a vacuum cleaner. The lock strength was adjusted until the door opened at a conservative over-pressure value of approximately 1.20 kPa. Five tests were conducted to ensure correct calibration. The results are shown below.

Table 2.2 Explosion panel test results.

Volts	**Pressure (kPa)**
5.64	1.43
5.43	1.38
5.01	1.27
5.25	1.33
5.77	1.47

Once the lock had been tightened in it was marked in is calibrated position, to indicate the correct location.

2.4 VENTILATION CONTROL.

In a compartment the ventilation opening does not often extend from the floor to the ceiling. In these experiments the ventilation opening had a lower sill, which was raised above the floor and base of the fire source to model a conventional window.

The door of the compartment originally had no opening for ventilation as a pressure integrity evaluation needed to be carried out to determine a structurally safe ventilation size. After the analysis for the pressure relieving panel was complete, it was determined that a maximum fixed ventilation opening of 0.5 m x 0.5 m square would be used. This ventilation hole was then cut into the centre of the door.

To be able to control the size of the ventilation for use in the experiments, this opening had to be able to be varied. Therefore 30 mm angle iron runners and PROMATECT® H sliding panels were fixed either side of the opening, so that the size of the ventilation could be varied both vertically and horizontally. Figure 2.5 shows the layout of the door with sliding panels.

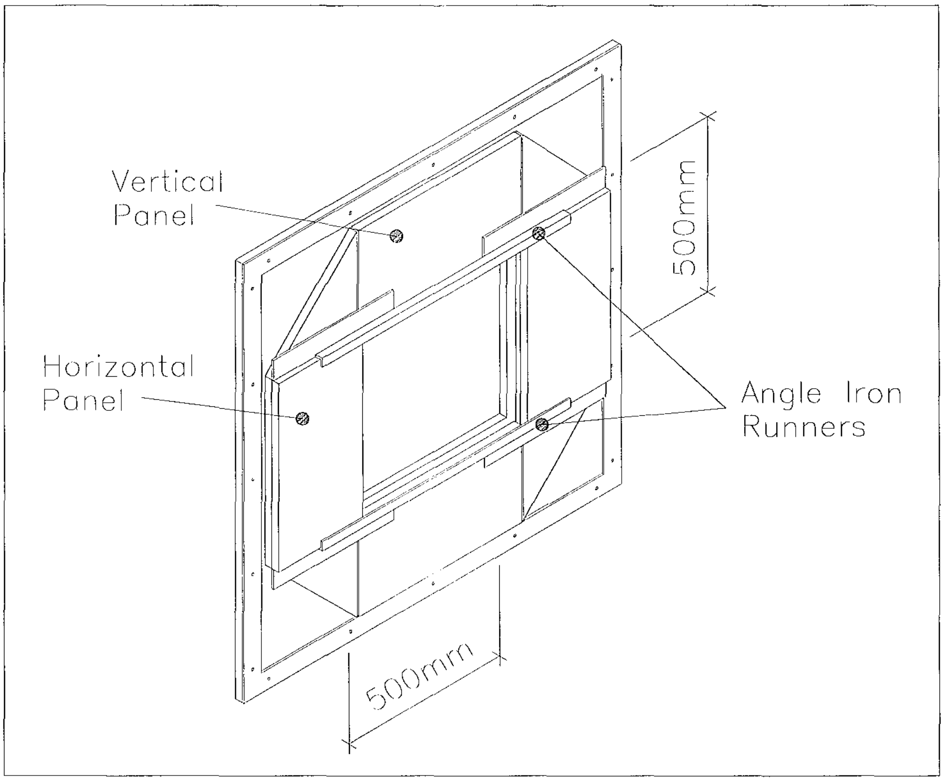

Figure 2.5 Adjustable ventilation sliding panels.

2.5 Fuel System

2.5.1 Fuel

Pool fires were used as they are one of the simplest geometry's that can be used for a diffusion flame. The common hydrocarbon fuel Heptane was used as it has consistent properties and burns not unlike thermoplastics. It can therefore be related back to practical situations. The easy repeatability of pool fires was also another advantage in experiments.

2.5.2 Pan Size

A 200 mm diameter circular pan, with a depth of 50 mm was used in all the experiments.

2.5.3 Fuel System Operation

The Heptane was pumped from a 19 litre fuel tank by a Masterflex tubing pump to a header tank. The photo in Figure 2.6, shows the layout of the fuel system in the experiments. A flat piece of steel with two bolts was welded to the back of the compartment base frame. This allowed the header tank to be fix by a couple nuts at the same height as the required fuel depth in the pan. It also permitted the header tank to be adjusted, to raise and lower the level in the pan. A hole drilled in the base of the compartment fixed the location of the fuel pan and allowed it to be feed fuel from the outside.

The pan was gravity fed from the header tank through tubing, which was connected to a pipe at the bottom of the pan. The header tank allowed a constant head of heptane to sit inside the pan with the overflow draining back to the fuel tank. This constant head was regulated by the speed of the pump and a window in the side of the header tank allowed the flow to be monitored.

The lip height was controlled to be approximately 1.0 cm for all the fires.

A schematic diagram of the fuel layout is shown in Figure 2.7.

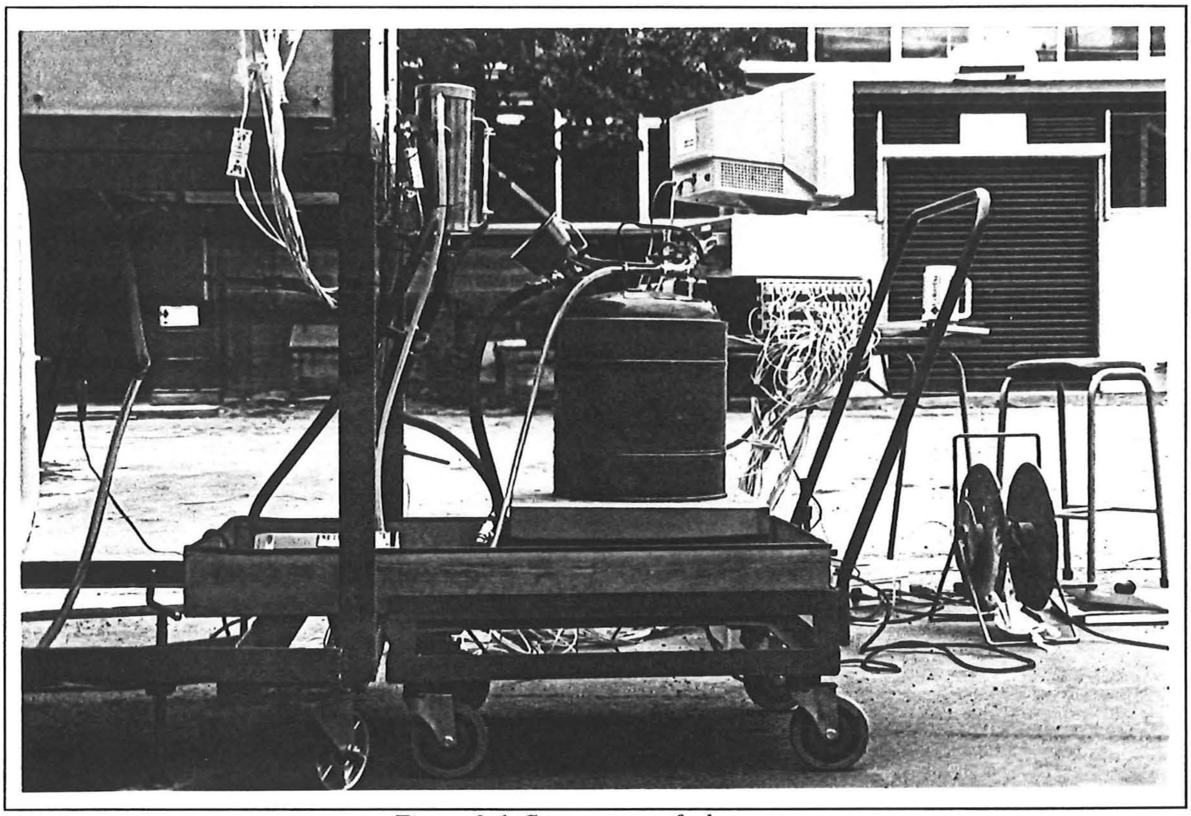

Figure 2.6 Compartment fuel system.

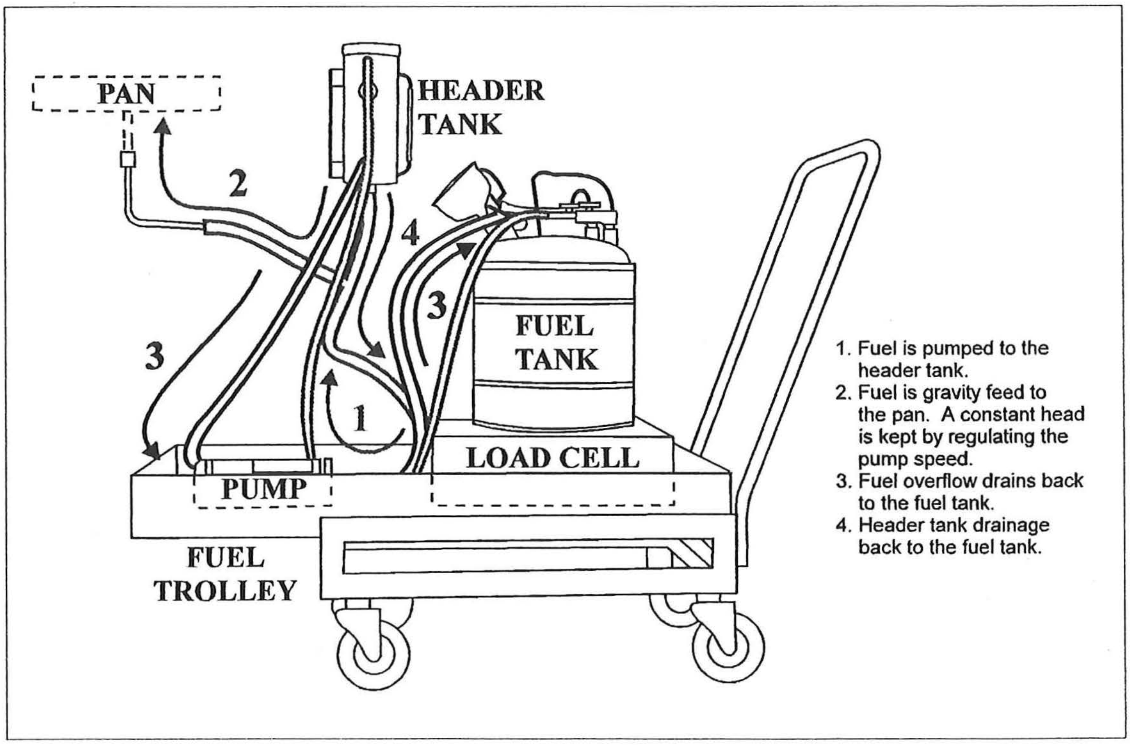

Figure 2.7 Diagram of compartment fuel system.

2.5.4 Ignition

The fires were started by pilot ignition.

2.6 Extinguishment System

A CO_2 system was set up in the compartment to extinguish the pool fires once an experiment had been completed, or in case something went wrong. This consisted of a CO_2 cylinder with regulator that lay at the front of the compartment base. A hose coming from the cylinder then split in two directions. Each hose feed a pipe terminating inside the compartment next to the walls, and just in front of the pan. All that was then required to extinguish the fire was to fully close the ventilation and open the valve on the CO_2 cylinder.

2.7 Phase 1 Experiments

2.7.1 Summary of Experiments

Two initial tests were run as trials to determine the compartment's integrity, and to ascertain its behaviour when subjected to fire. These tests were also conducted to ensure the fuel system and instrumentation were functioning correctly. These tests were run for approximately 15 minutes with the vent fully opened, and temperatures of up to 600°C were achieved (see Appendix B1).

No problems with the compartment and fuel system were found but a thermocouple connection was found to be faulty and subsequently fixed.

The third test was run as the first full length experiment. The ventilation was set at the maximum height of 500 mm, with the width being increased every half hour from 125 mm, to 250 mm and then finally to 375 mm. Half way into the last ventilation stage the fire had grown until flames projected out of the vent. Temperatures of up to 1000°C were reached, and it was noticed that liquid was dripping down the inlet pipe leading from the header tank to the pan. Therefore the experiment was halted. It was subsequently found that the liquid was the result of water being evaporated from the Gib® Fyreline.

However due to the high temperatures obtained within the compartment, the PROMATECT® H lining with its negative coefficient of expansion, cracked and bowed as water was differentially evaporated from the boards. This resulted in the boards pulling away from the walls. On examination of the wall panel fixings, it was found that the screws did not penetrate far enough into the next layer to provide enough resistance against the pull out force.

Data supplied by the manufacturer (see Appendix A1), gave a coefficient of expansion of -6.4×10^{-6} (m/m K) within the temperature range of 20-600°C. This meant that for the 1.2 m long layers on the walls would contract approximately 9.8 mm.

It was decided to keep the contraction of the PROMATECT® H boards to a minimum. Thus the boards were cut into approximately 200 mm square tiles. This would prevent the boards from contracting too much, and also keep cracking to a minimum. As temperatures well in excess of the PROMATECT® H specification temperature range were obtained, subsequent testing in a furnace was carried out to determine the board's behaviour at higher temperatures.

2.7.2 Furnace Testing of Promatect® H

2.7.2.1 Single Layer Tests

A tile of approximately 200 mm square was cut and tested in a furnace. The photo in Figure 2.8 shows the tile in the testing furnace.

Initial dimensions were measured with vernier callipers across the centre of both sides of the boards. These dimensions were checked with the measurements obtained after exposure to high temperatures in the furnace (see Appendix C).

The sample was placed in the furnace at 500°C for two hours, with 3 readings taken every hour and averaged. This procedure was then repeated for temperatures of 750°C and 1000°C (see table 1, Appendix C). Difficulty was encountered in measuring the dimensions of the board to a high accuracy with the vernier callipers due to the radiative temperature from the board and its fibrous cohesion deteriorating as the testing continued. It was also noticed that the board cooled quickly accompanied by an increased contraction.

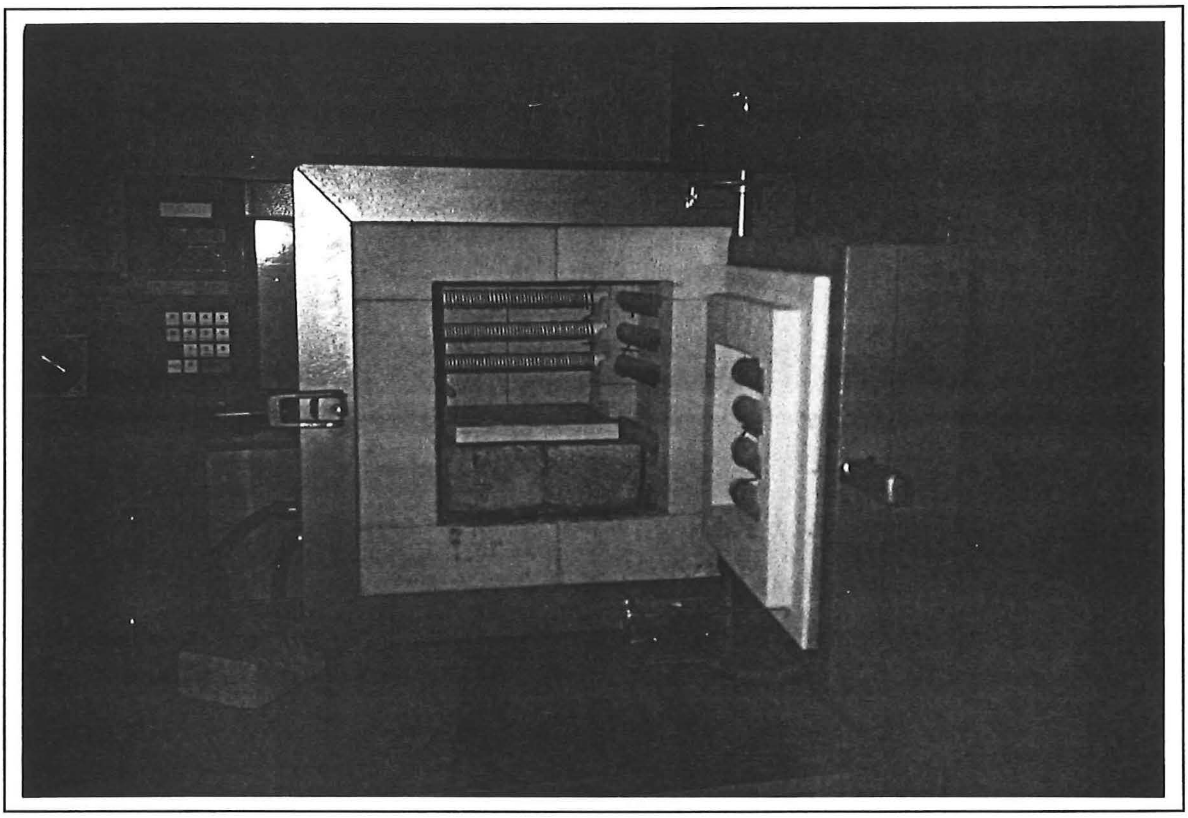

Figure 2.8 Single Layer PROMATECT® H Test.

The board was then left in the furnace at a temperature of 1000°C overnight and its dimensions remeasured in the morning (see Table 2, Appendix C). Due to the observation of an increasing contraction during the cooling process, the boards dimensions were also measured every 5 minutes after removal from the furnace until negligible change was recorded (see table 3, Appendix C).

The tile was then reheated to 1000°C for another two hours to determine any effects due to repeated heating (see table 4, Appendix C).

Table 2.3 shows a summary of the results obtained, with the amount of contraction being taken with respect to the initial dimensions. It can be seen that the PROMATECT® H board contracts when heated at high temperatures, but in addition, also contracts at a further accelerated rate when cooling takes place.

Table 2.3 PROMATECT® H Contraction.

		Contraction (mm)	
Temperature	**Time**	**NS Side**	**EW Side**
500°C	2 hours	-0.13	-0.03
750°C	2 hours	-0.51	-0.31
1000°C	2 hours	-0.81	-0.51
1000°C	2 hours	-1.09	-0.18
Cooling Down from 1000°C	N/A	-2.01	-0.97

2.7.2.2 Double Layer Tests

A two layer test was conducted to determine whether the tiles would have differential shrinkage causing bowing, as had occurred in the experiment,. Two layers of PROMATECT® H tiles were placed back to back on two layers of Kaowool and exposed to 1000°C for two hours. Both sides of each layer were measured and compared to the initial dimensions. No distinguishable bending of the boards was noticed.

2.7.2.3 Double Layer Tests with Connection

The double layer experiment was repeated again. This time it included the wall/tile attachment, to determine its fire resistance ability. The photo in Figure 2.9 shows the two tile layout in the testing furnace. This consisted of a screw and washer counterbored into the tile, and self tapped into a self drilled plasterboard fixing. The top of the screw and washer were exposed to the heat from the furnace elements during the experiments. The screw/washer and fixing withstood temperatures of 1000°C well into the first hour, but after the second it was found that the screw head had fused with the washer and the plasterboard fixing had partially melted.

This method of fixing was far more conservative than that to be used in the final compartment, as it allowed primary conduction through the screw into the plasterboard fixing. The final method of fixing was to involve a PROMATECT® H cap over the screw.

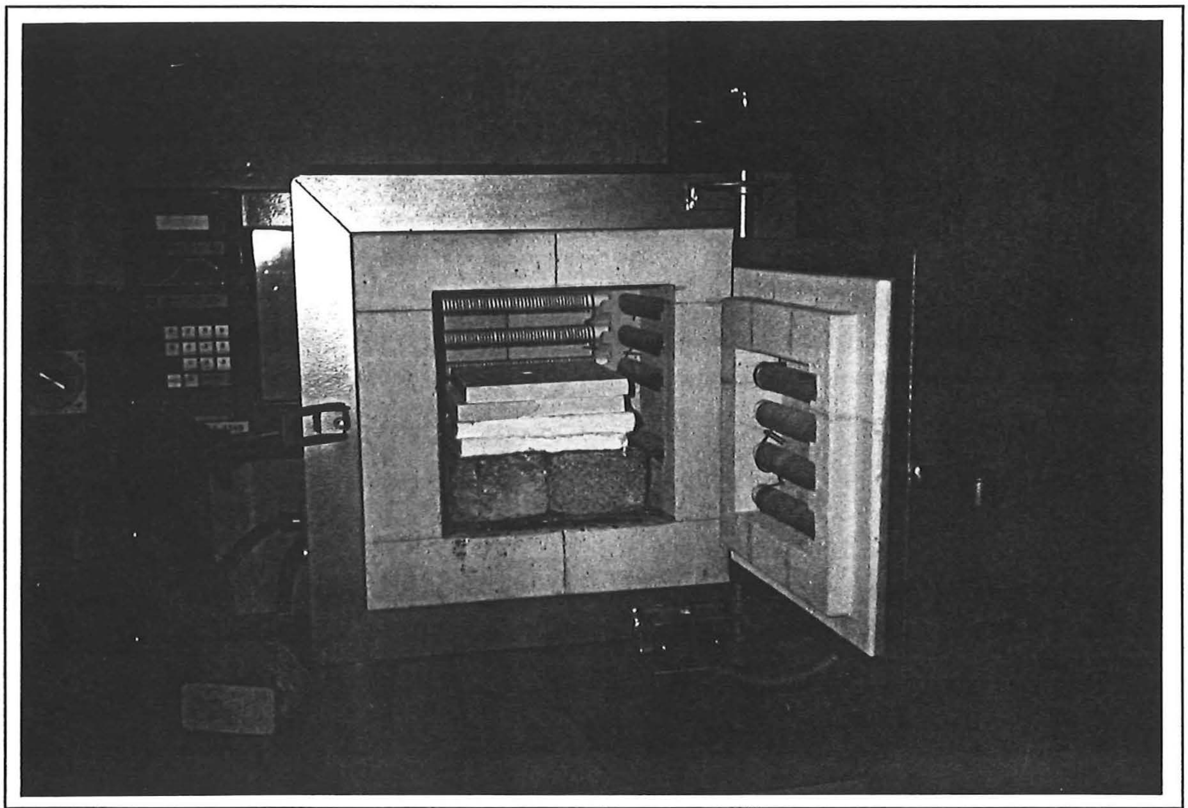

Figure 2.9 Double Layer PROMATECT® H Test.

2.7.2.4 Double Layer Tests with Capped Connection and Multiflex Sealing

The above test was repeated with the fixing being capped with a plug of PROMATECT® H sealed with Multiflex fire rated flexible acrylic sealant. The fixing withstood the temperatures well in the first hour, as during the initial double layer testing with fasteners. However at the end of the second hour the fixings had melted to a lesser degree than before and the flexible sealer had become hard and brittle.

2.7.3 Compartment Changes

As all the above tests were more severe than that encountered in the experimental tests to date, it was thought that the tile layout would provide sufficient fire resistance. Therefore 88 tiles were made and fixed to the inside of the compartment using screws and self drill plasterboard fixings, with sealed caps over each screw.

2.8 PHASE 2 EXPERIMENTS

2.8.1 Compartment Layout

The compartment at this stage consisted of an inside facing layer of 88 PROMATECT® H tiles on the walls and roof. Tiles were also made for the floor, and all were fixed by screws and self drill plasterboard fixings. Figure 2.11 shows the tile layout inside the compartment. The screws were counterbored and covered by a cemented PROMATECH® H cap. All the panels were butted jointed together and sealed with a glass fibre rope as shown in the detail in Figure 2.10. The outer two layers consisted of PROMATECH® H and 20 mm Gib® Fyreline, as originally constructed.

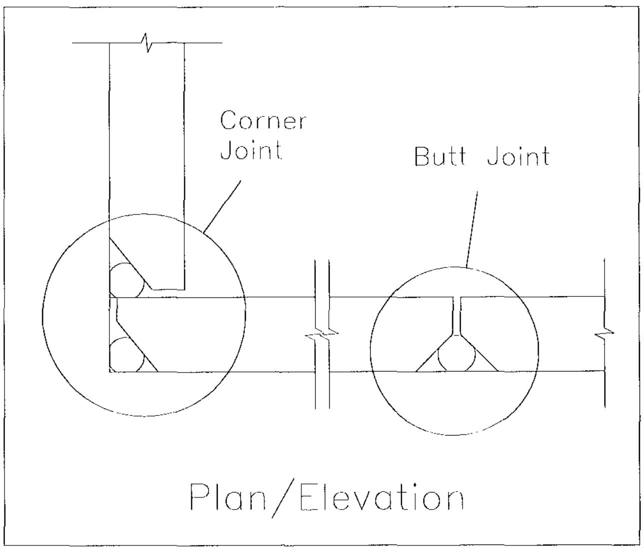

Figure 2.10 PROMATECT® H Tile configuration.

Surface/Radiation thermocouples were also added to the compartment at this stage. The locations of these thermocouples can be seen circled in Figure 2.11 below.

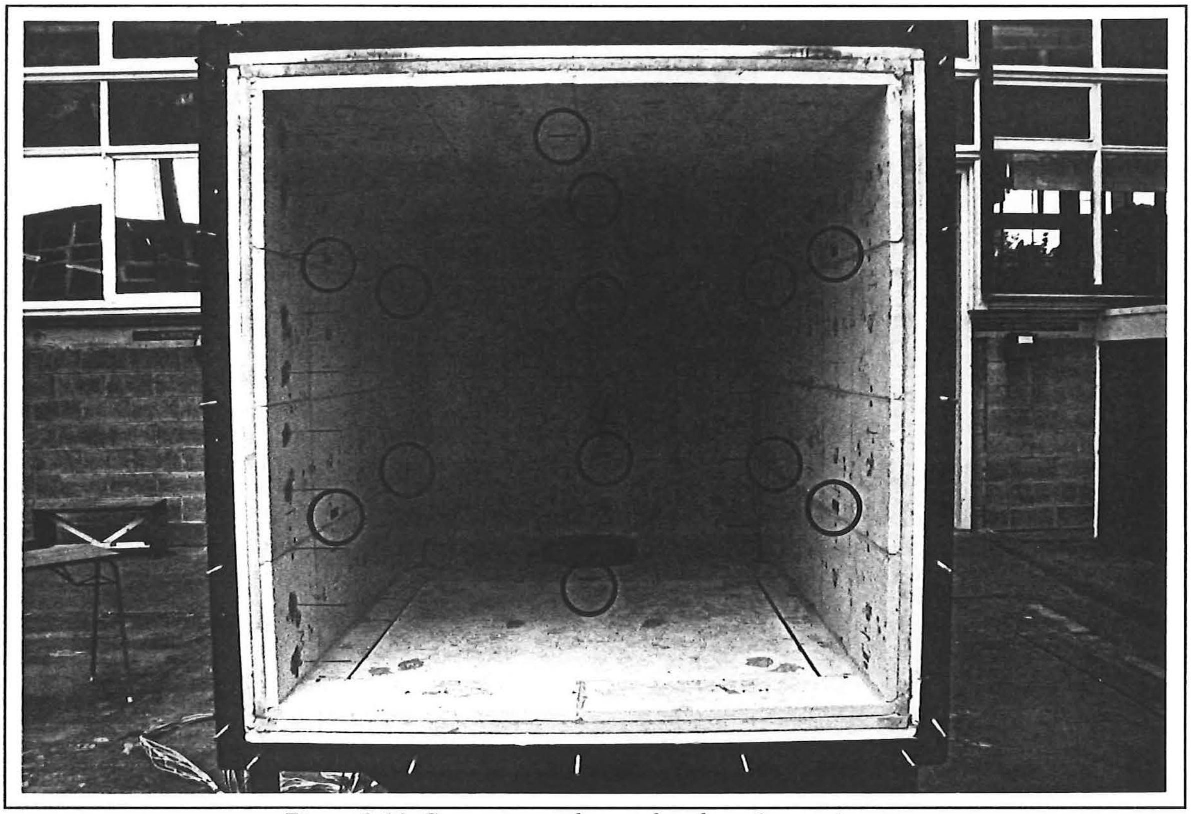

Figure 2.11 Compartment layout for phase 2 experiments.

2.8.2 Summary of Experiment

An experiment was conducted with the ventilation at full height and 250 mm wide for a period of two hours (see Appendix C2). Within this time excess pyrolozates accumulated to such a degree that in the last half hour of the burn, flames again extended out the door. On extinguishment of the fire the PROMATECT® H boards fell off the ceiling. It is thought that the glass fibre rope was helping to keep the boards in place during the fire but once the fire had been extinguished the boards contracted at a higher rate. This along with a partial melting of the fixings, caused the boards to fall.

2.8.3 Compartment Changes

The last resort was to line the inside of the compartment with Kaowool, a ceramic fibre blanket. This was done by welding stainless steel spikes to lengths of 50 mm x 5 mm flat, and fixing them to the walls. The Kaowool was then pushed onto the spikes and fixed by washers that turned and locked the fabric in place. Three layers of Kaowool were placed onto the walls in an alternating wrapped pattern, to ensure that each seam was overlapped and that heat transfer to the Gib® Board was minimal. The photo in Figure 2.12 below, shows the layout of the Kaowool in the compartment.

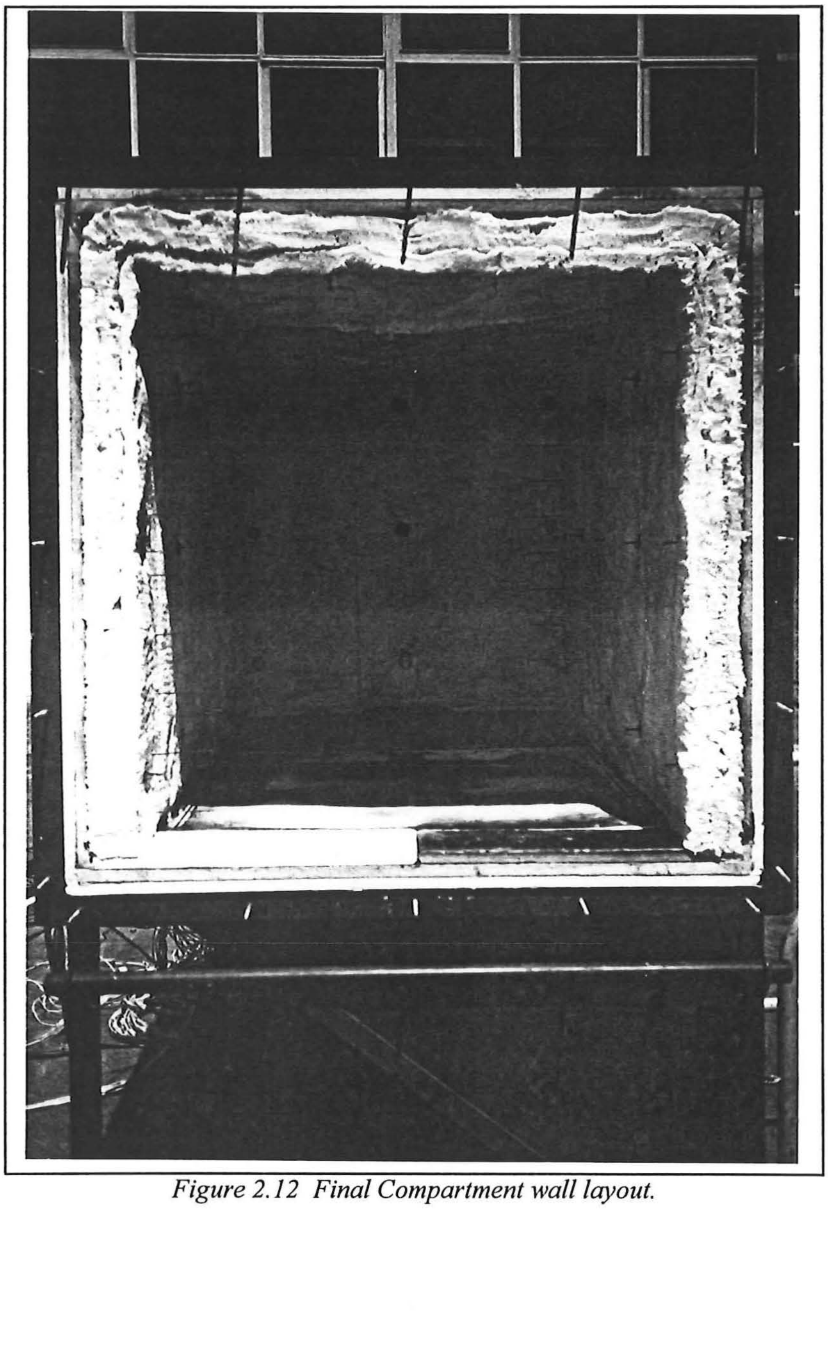

Figure 2.12 Final Compartment wall layout.

2.9 Final Compartment Layout

After the Kaowool had been fitted to the compartment the interior dimensions had changed to approximately, 975 mm high, 950 mm wide and 1475 mm deep.

A diagram of the compartment is shown in Figure 2.13.

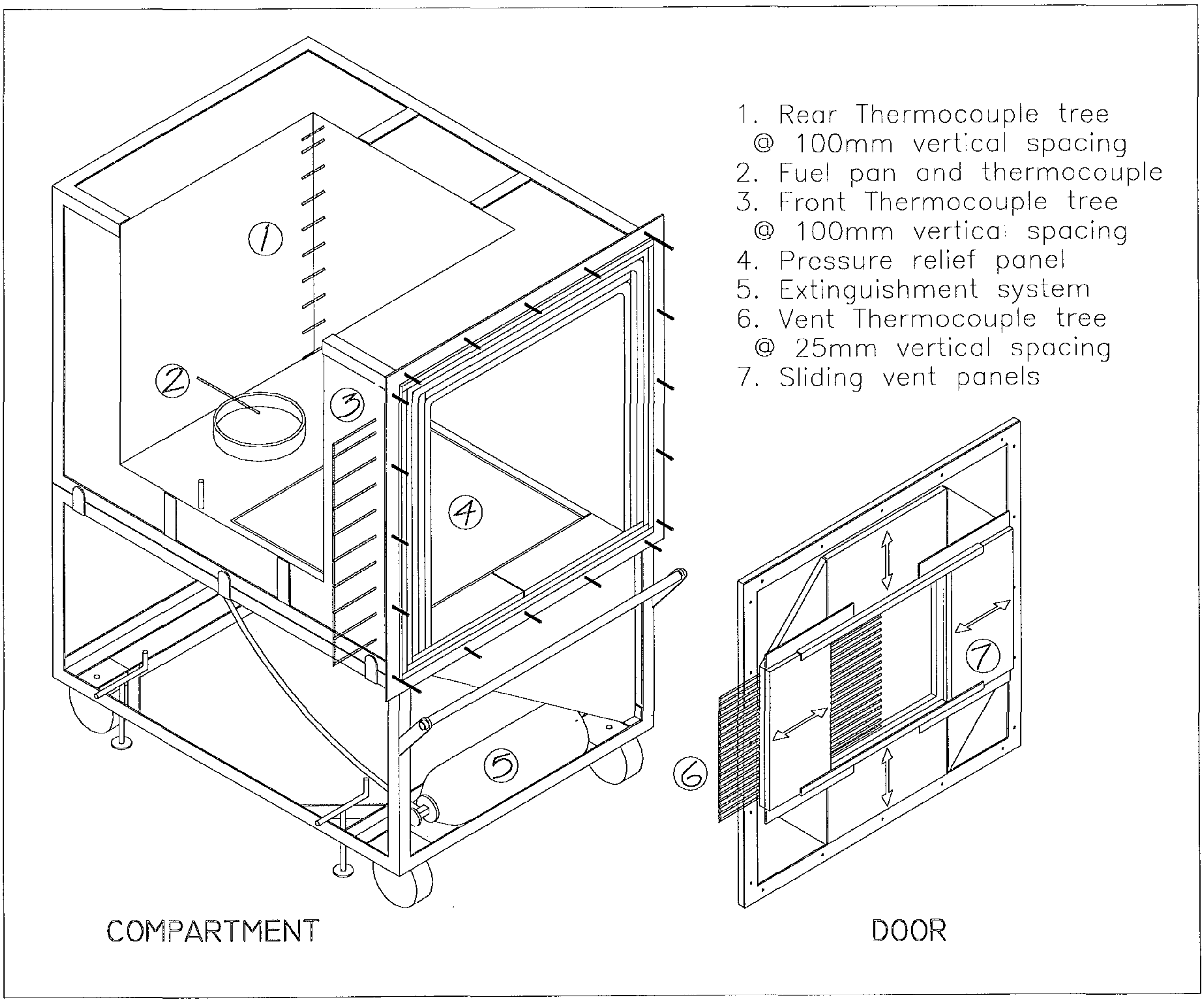

Figure 2.13 Final Compartment layout.

2.10 PHASE 3 EXPERIMENT

The compartment was tested with a fire for two hours. The ventilation opening began initially at 375 mm high by 125 mm wide. This was reduced three times to finish at 125 mm high by 62.5 mm wide. Temperatures of up to 1000°C were achieved (see Appendix C3), and a backdraft also occurred. No problems with the compartment were found. The pressure relief panel had also bowed due to differential evaporation of the PROMATECT® H boards, and the high temperatures influencing the steel frame of the door. This caused a small amount of unwanted ventilation to leak in through the gaps created in the tiered layers of the pressure panel. The floor over the release panel was therefore covered with a layer of Kaowool to prevent flame spread out of the panel at the bottom and to minimise leakage.

Chapter 3. Instrumentation

3.1 TEMPERATURES

Temperatures were monitored both inside and out of the compartment. The temperature profiles obtained from the experiments were later used for vent flow analysis. Figure 3.1 shows the locations of the thermocouples in the compartment.

3.1.1 Compartment Temperatures

To measure the compartment gas temperatures, vertical thermocouple trees were placed at the front and rear of the container (see Figure 3.1). Two sets of 10, 1.6 mm diameter type K stainless steel clad thermocouples were used and positioned at a spacing of 100 mm vertically between the floor and ceiling. To avoid effects from the boundary layer, the thermocouples were placed 100 mm off the wall/door boundaries and 50 mm from the floor/roof. This layout was used in the both the initial experiments, where the compartment walls consisted of PROMATECT® H.
However due to the increase in thickness of the compartment walls when the Kaowool was fitted after the initial experiments, the top thermocouple on each of the compartment thermocouple trees became enclosed within the Kaowool layers. Therefore both of these thermocouples were moved down until they were 50 mm above the next on the tree. The increase in wall thickness had also moved the physical boundary limits so that the back thermocouple tree was now 50 mm off the back wall.

A single thermocouple was placed 20 mm above the centre of the fuel pan to obtain a reading of the flame temperature above the source of the fire.

3.1.2 Wall Temperatures

Temperatures between the layers of lining materials were monitored by thermocouples. One set of thermocouples was placed between the outer layer of Gib® Fyreline and second layer of PROMATECT® H. The second set was located between the two PROMATECT® H layers or when the compartment was changed, between the PROMATECT® H and Kaowool. These were located in various positions around the compartment which can be seen in the drawing below in Figure 3.1.

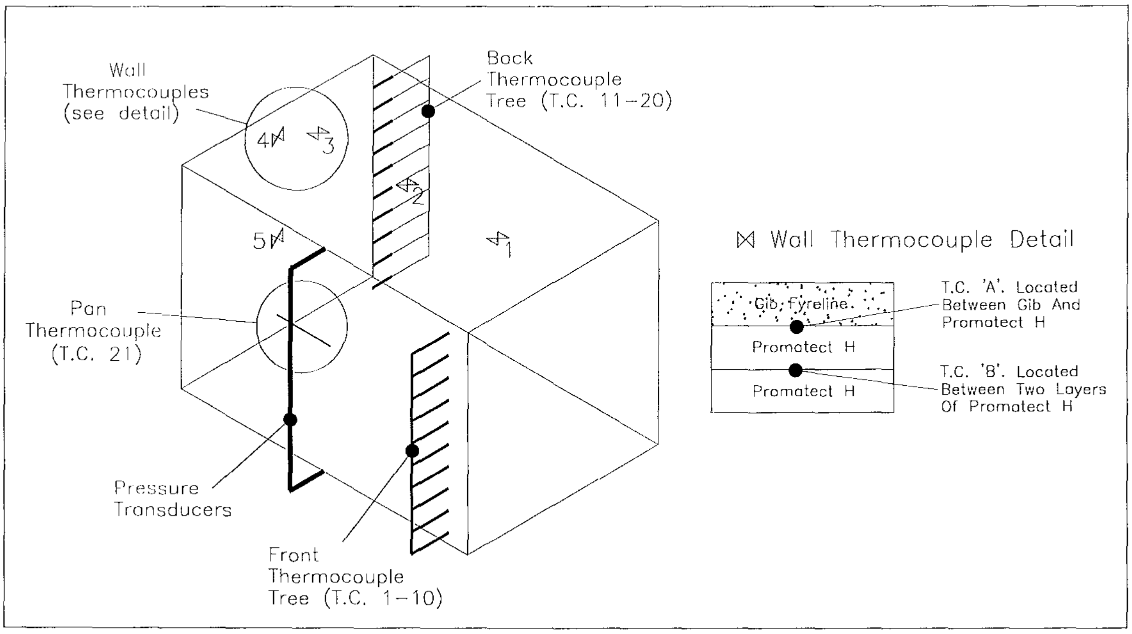

Figure 3.1 Instrumentation locations

3.1.3 Vent Temperatures

A thermocouple tree was placed within the vent to record the vent flow temperatures and subsequently calculate the mass flows rates. Therefore the thermocouples are spaced closer together to gain a more detailed representation of the temperature profile within the door. A diagram of the thermocouple layout in the vent, in shown in Figure 3.2.

Initially in the Phase 1 experiments (see Chapter 2), 13 type K bare bead 24 gauge with high temperature glass insulation thermocouples were placed within the vent. The first and last three thermocouples were spaced at 50 mm vertically, with those remaining in the centre at 25 mm (see Figure 3.2). However these thermocouples were easily displaced from their correct locations, and needed to be repositioned and checked frequently. They were therefore replaced with 20, 1.6 mm diameter type K stainless steel wire thermocouples for the remaining experiments. These were spaced 25 mm apart vertically with the first and last thermocouple 12.5 mm off the respective opening boundaries (see Figure 3.2).

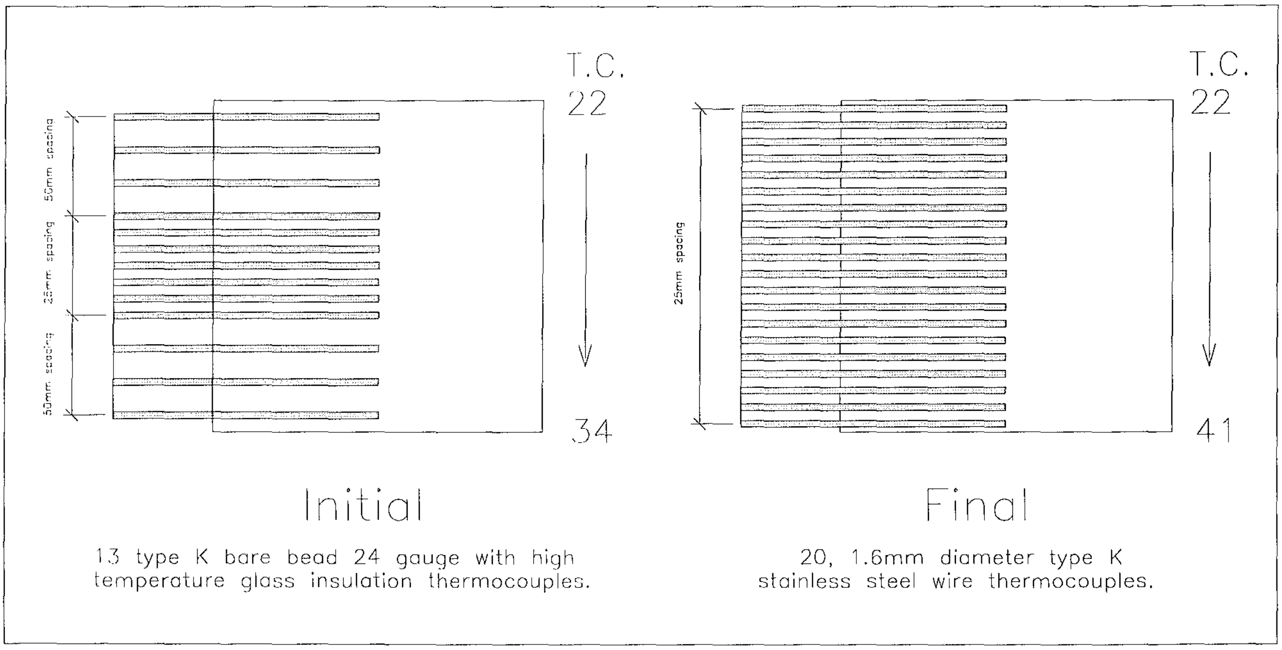

Figure 3.2 Vent thermocouple layout.

3.1.4 Surface/Radiation Temperatures

In the Phase 2 experiments (see Chapter 2), a total of 13 K bare bead 24 gauge with high temperature glass insulation thermocouples were placed within the compartment. Four were placed on each of the side walls, two on the back wall, two on the roof and one in front of the pan on the floor (see Figure 2.11). A small channel was scraped into the PROMATECT® H board at the location of the thermocouples, orientated in the direction of the temperature isotherms that would occur in the compartment. A hole was then drilled to the outside, and the thermocouple wire fed through. Approximately 25 mm of the thermocouple wire was cemented along the channel with an industrial low expansion cement, with the bead level to the PROMATECT® H board surface.

At the conclusion of this set of experiments the walls and roof panels were replaced and the thermocouples removed. Wall and roof surface/radiation temperatures were not recorded during the rest of the experiments. However the thermocouple situated on the floor in front of the pan was retained.

3.2 PRESSURES

Compartment pressures were monitored through the first and second Phase experiments. Pressure probes were placed at the very top and bottom of the compartment, which can be seen in the instrumentation diagram in Figure 3.1. These were connected to two pressure transducers with a pressure range of 0-25 Pa. However after the initial experiments they were removed, as the pressures recorded were insignificant due to the small relative height of the compartment.

3.3 MASS LOSS

The mass loss of the fuel was recorded on a load cell upon which the fuel can sat (see Chapter 2). The initial mass was recorded at the start of each experiment for calibration.

3.4 Weather Conditions

As the weather plays a big part in the way in which a fire behaves, a mobile weather station was set up beside the compartment to measure wind speed and direction. The photo in Figure 3.3 show the layout of the weather station.

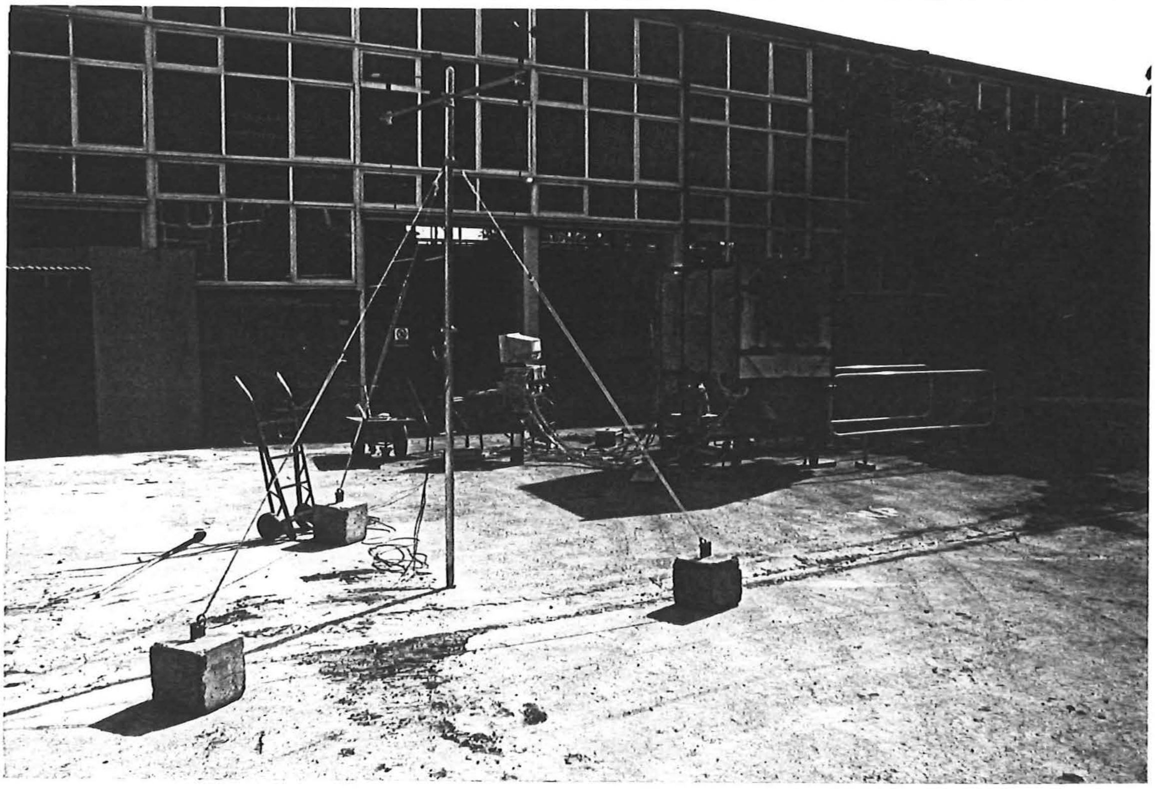

Figure 3.3 Mobile weather station.

The ambient temperature was recorded using a type K wire thermocouple. Humidity was not recorded.

3.5 Data Acquisition

A 486 DX/66 computer was used to continually monitor and collect the data from each experiment. The data was read 10 times a second and averaged over 5 seconds, then recorded. An initial period of three minutes was sampled before ignition as a calibration. The time was kept by a digital clock started at the point of sampling.

The photo in Figure 3.4 shows the compartment instrumentation and experimental layout.

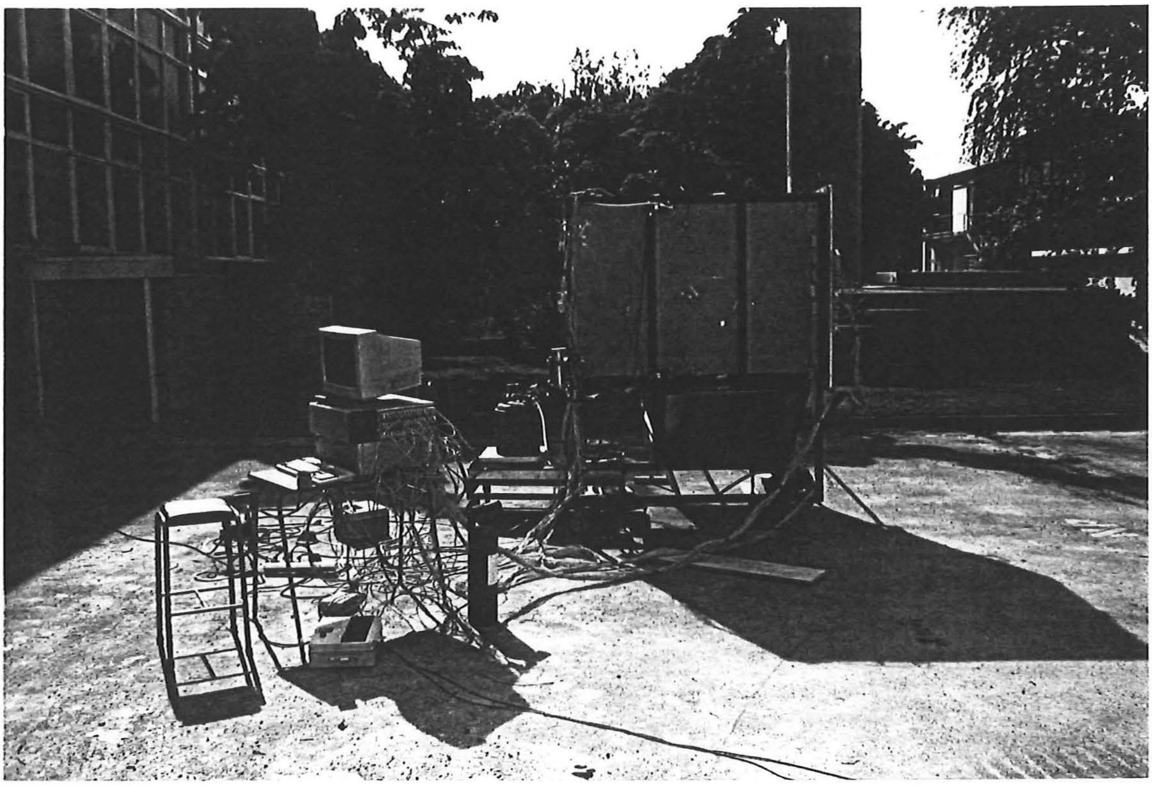

Figure 3.4 Compartment and Instrumentation layout.

Chapter 4. Testing Program

4.1 Results From Initial Tests

The aim of this project was to control the ventilation into the compartment and to force the fire to burn to extinction. The initial experiments that were run to ascertain the integrity of the compartment, showed that continuous burning was achieved and sustained at vent openings down to 125 mm in width (see Appendix B). Therefore the ventilation was not being limited, at this size of opening.

So a program was drawn up to uniformly reduce the vent opening in calibrated steps, and hopefully force the fire to extinction.

4.2 Experimental Program

4.2.1 Compartment Fires

It was decided to run a series of experiments at the maximum height of the compartment door, of 500 mm. The width of the ventilation was also systematically reduced from 125 mm, to 62.5 mm, to finally 32.25 mm.
The top vertical ventilation door panel was then lowered down to 125 mm, and then to 250 mm, effectively increasing the size of the soffit. This made the actual height of the vent opening, 375 mm and 250 mm respectively. At each lowering stage, the reducing width cycle was repeated as above.

Table 4.1 overleaf shows the testing program carried out with the resulting ventilation opening areas.

Table 4.1 Testing Program and Vent Areas (m²).

	Width of Opening		
Height of Opening	125 mm	62.5 mm	32.5 mm
500 mm	0.0625	0.0313	0.0163
375 mm	0.0469	0.0234	0.0122
250 mm	0.0313	0.0156	0.0081

The relative proportions of these openings can be seen in Figure 4.1 below.

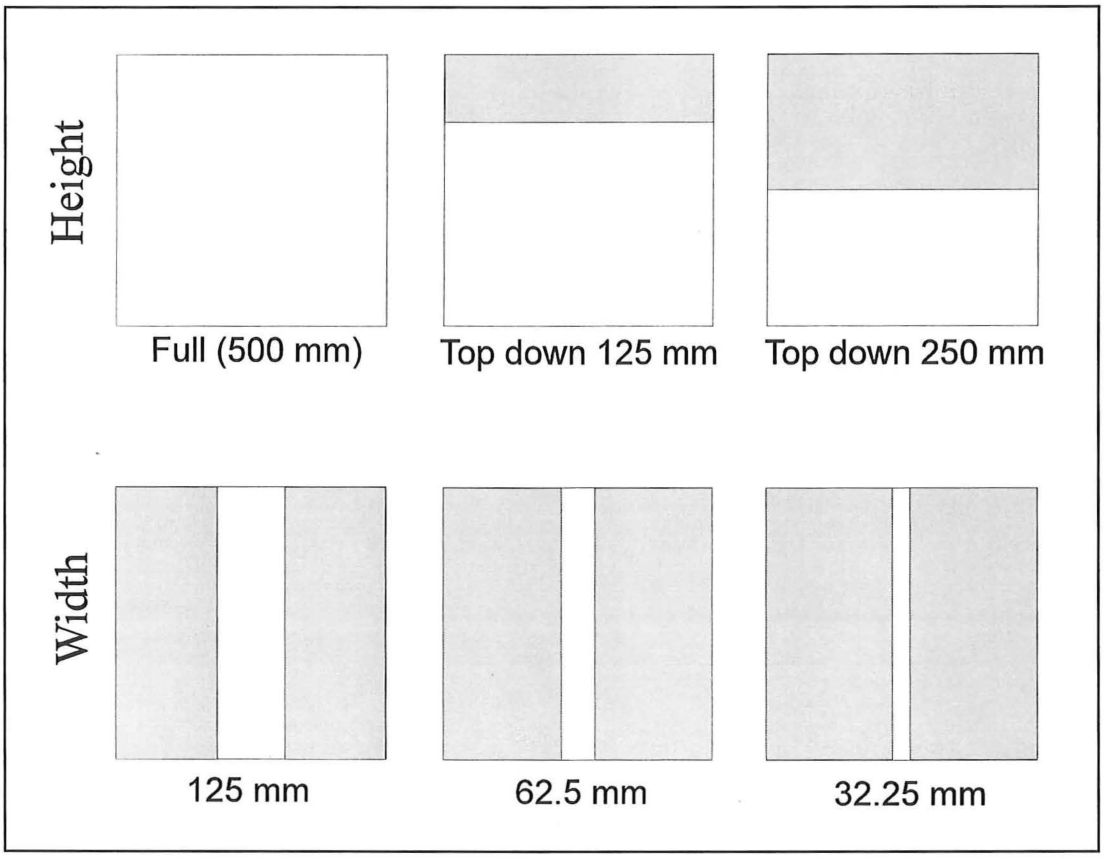

Figure 4.1 Vent size proportions.

The lower vertical door panel was also raised 250 mm to see the effect on compartment fires when there is a change in the sill height. This experiment was conducted with the ventilation width set at 125 mm.

4.2.2 Free Burning pool Fire Test

A free burning fire test was also conducted to determine the mass loss rate of the fuel burning in the open. The fuel system was connected up to record the mass loss from the pan in a free burning fire. A thermocouple was also placed over the pan to record the source flame temperature.

Chapter 5. Data Analysis

5.1 VENT FLOWS

The ventilation controls the flow of air and gases in a compartment, and intrinsically the way that the fire develops. In developing fires the air flow controls the temperature and the heat transfer. Subsequently once flashover has been achieved, it is known that the air flow controls the mass loss.

The results of the experiments conducted in this study, address the problem of vent flows once the compartment has achieved a steady state. It is therefore important to show the effect of the ventilation size on fire strength and flow rates.

5.1.1 Flow Rates

Flows in and out of fire compartments are driven by pressure differences across the vent. Within the compartment the velocities are negligible, except for locally in flames, plumes and wall jets. Therefore the pressures within the compartment are of the order of a few Pascal. It is very hard to measure and record pressure data at such low levels and results are usually very noisy due, mainly, to turbulence (see the Pressure Data from initial experiments in Appendix B). Generally the fire induced flow rates have been calculated by a hydrostatic method through temperature profiles and one static pressure difference measurement [5]. Marc Janssens *et al.* [6], developed a technique to calculate the fire induced flow rates using only temperature profiles, which has been applied in this project. The change in density within a compartment and the subsequent change in pressure, can be calculated as a function of the height, if the temperature profile measured inside the compartment is known.

The vent flow formulae have the following form when adjusted to the parameters of the compartment used in the experiments :

$$\dot{m}_i = 1563\ C_i\ W_d \int_{z_{db}}^{z_n} \left[\frac{1}{T_d(z')} \int_0^{z_n} \left(\frac{1}{T_\infty} - \frac{1}{T_i(z'')} \right) dz'' \right]^{1/2} dz' \qquad \text{...............(5.1)}$$

Similarly, the inflow rate is equal to :

$$\dot{m}_o = 1563\ C_o\ W_d \int_{z_n}^{z_{dt}} \left[\frac{1}{T_d(z')} \int_{z_n}^{z_{max}} \left(\frac{1}{T_\infty} - \frac{1}{T_i(z'')} \right) dz'' \right]^{1/2} dz' \qquad \text{............(5.2)}$$

Where :

W_d = width of ventilation opening (m)
z_n = height of neutral plane (m)
z_{db} = height of the bottom of ventilation opening (m)
z_{dt} = height of the top of ventilation opening (m)
T_∞ = temperature of ambient air (K)
T_i = temperature inside the compartment (K)
T_d = temperature within vent (K)

This can be shown diagrammatically in Figure 5.1 below

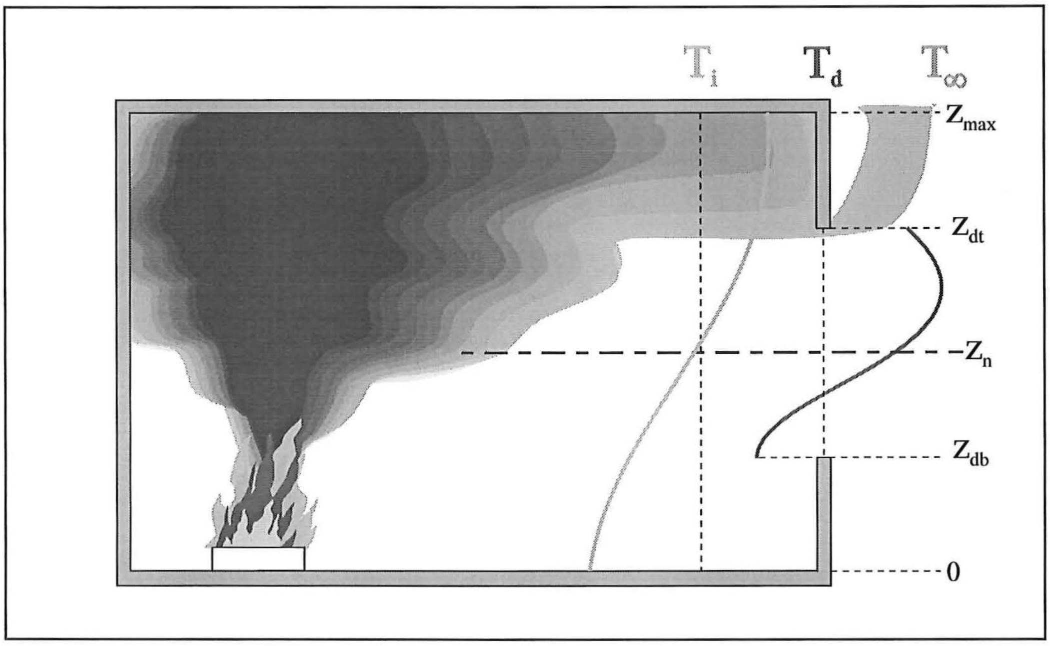

Figure 5.1 Compartment vent flow analysis diagram.

Before a value for the mass flow can be found, the neutral plane height (z_n) is needed as one of the limits of integration. The neutral plane height is the point within the vent where there is no flow. Consequently, there is inflow below this point and outflow above.

5.1.2 Neutral Plane

The neutral plane is located using conservation of mass criteria. The mass balance equation used has the following form :

$$\frac{dm_r}{dt} = \dot{m}_i + \dot{m}_v - \dot{m}_o \qquad \text{.....................................(5.3)}$$

Where :

$$\begin{aligned} m_r &= \text{mass accumulated inside the compartment (kg)} \\ \dot{m}_i &= \text{inflow rate (kg / s)} \\ \dot{m}_v &= \text{release rate of fuel volitiles (kg / s)} \\ \dot{m}_o &= \text{outflow rate (kg / s)} \end{aligned}$$

Usually the release rate of fuel volatiles, m_v , term is very small compared to the other terms in Equation (5.3) and can be neglected. The mass balance equation may then be written as a sum of the inflow and outflow, Equations (5.1) and (5.2) respectively, resulting an equation of the following form :

$$C_i \int_{z_{db}}^{z_n} \left[\frac{1}{T_d(z')} \int_0^{z_n} \left(\frac{1}{T_\infty} - \frac{1}{T_i(z'')} \right) dz'' \right]^{1/2} dz' \\ - C_o \int_{z_n}^{z_{dt}} \left[\frac{1}{T_d(z')} \int_{z_n}^{z_{\max}} \left(\frac{1}{T_\infty} - \frac{1}{T_i(z'')} \right) dz'' \right]^{1/2} dz' = 0 \qquad \text{.......(5.4)}$$

It is then a case of iterating Equation (5.4), to solve for the neutral plane height (z_n). A model was written to perform the iteration, using the compartment and vent temperature profiles obtained during the experiment, and relative door heights.

Once z_n had been found the mass flow rates into and out of the compartments can be calculated from Equations (5.1) and (5.2) respectively.

5.2 Mass Loss Rates

As mentioned in Chapter 3 the experimental mass loss rates were measured with the use of a load cell. The experimental results are compared with empirical correlations to determine if the theoretical equations correspond to what has been obtained experimentally.

5.2.1 Correlations

5.2.1.1 Free Burning Fires

Babrauskas [7] has shown that the following equation can be used to represent the mass loss rate of an open pool fire.

$$\dot{m} = \dot{m}''_{\infty}\left(1-\exp(-k\beta\, D)\right)A_p \qquad \text{..........................(5.5)}$$

Where :

$$\begin{aligned} \dot{m}''_{\infty} &= \text{mass loss rate for an infinite diameter pool (kg / m}^2\text{s)} \\ k &= \text{extinction - absorption coefficient of the flame} \\ \beta &= \text{mean - beam - length corrector} \\ A_p &= \text{pool area (m}^2\text{)} \end{aligned}$$

However, it must be kept in mind that the typical pool fire does not burn in a completely steady state manner. The burning rate increases as time goes on, due to the process of heating present physical boundaries. This correlation is also based off experiments conducted on pool fires of diameter greater than 200 mm. Therefore is validation to pool fires less than 200 mm can be questioned.

It is also appropriate to use Equation (5.5) in room fires up to the point of flashover [7].

5.2.1.2 Stoichiometric Room Fire Effects

It has long been observed that pool fires can burn in a high fuel rich manner. Babrauskas [7] has also shown that the stoichiometric fuel pyrolysis rate can be estimated as :

$$\dot{m}_p(\mathrm{st}) = \frac{0.5}{r} A_v \sqrt{h_v} \qquad \text{.....................................(5.6)}$$

Where :

r = stoichiometric air / mass ratio = 15.1 for heptane
A_v = vent area (m^2)
h_v = vent height (m)

5.2.1.3 Stoichiometric Energy Balance

The stoichiometric energy balance mass loss has the following form :

$$\dot{m}'' = \frac{A_p \,\sigma\, (T_f - T_b)^4}{\Delta h_p} \qquad \text{............................(5.7) [8]}$$

Where :

A_p = pool area (m^2)
σ = Stefan - Boltzmann Constant (5.67×10^{-8} W m^{-2} K^{-4})
T_f = fire temperature (K)
T_b = boiling point temperature (K)
Δh_p = heat of gasification (J kg^{-1})

These correlations are compared with the mass loss obtained during the experiments.

5.3 HEAT RELEASE RATE

The use of thermoplastic fuels in the experiments, has as wide ranging effect, as the data can be correlated to practical fire situations.

The heat release rate can be obtained easily once the mass loss rate has been determined by multiplying it by the heat of combustion (ΔH_c).

5.4 VENTILATION FACTOR

The burning rates of compartment fires are strongly dependent upon the size and shape of the ventilation opening. Kawagoe (1958), measured that the burning rate of wooden cribs in compartment fires, and determined the following correlation [9]

$$\dot{m} = 5.5\, A_v\, h_v^{1/2} \qquad \text{...(5.8)}$$

Where :

A_v = vent area (m^2)
h_v = vent height (m)

Theoretical analysis of the flows in and out of a compartment also derived the above correlation [9]. The common denominator $A_v\ h_v^{1/2}$ was found and is called the 'ventilation factor'. It is used to compare the results obtained in these experiments with the empirical correlations.

5.5 ZONE MODEL COMPARISON

As experimentation is not a viable option of evaluating fire behaviour in most situations, computer models have a greater potential for engineering applications and are used to compare the results of the experiments. Computer Modelling is the most readily available option for the modelling the behaviour of fire. The package chosen here for comparison is the program CFAST (Consolidated Model of Fire Growth And Smoke Transport). CFAST was used due to wide spread use in the engineering world.

6.5.1 CFAST Model

CFAST is a model which is intended to predict fire growth and smoke transport in multi-compartment structures [10]. The results obtained were used to determine if model behaviour corresponded to what was obtained and visualised experimentally.

6.5.1.1 Input

The compartment dimensions entered were 0.95 m wide, by 0.98 m high, by 1.48 m long. The lining materials consisted of Kaowool on the walls and roof, and gypsum on the floor. For all of the experiments modelled the sill height was located at a height of 0.25 m, but the soffit height was reduced from 0.75 m, to 0.625 m, to 0.5 m. The widths of the ventilation opening were also changed from 0.125 m, to 0.625 m, to finally 0.3125 m. The fire was located in the rear of the compartment corresponding to the pan position at 0.28 m off the back wall, 0.475 m off the side walls, and raised up 0.05 m. The corresponding steady state heat release rate for each experimental ventilation opening was selected, as the design fire. A 1% oxygen constrained fire was then run for one hour and the results compared to those obtained in the experiments. A copy of the general CFAST input, can be seen in Appendix E.

Chapter 6. Results and Discussion

Fourteen compartment tests were conducted along with one free burn fire. The data from each experiment gave a mass loss curve, front, back, vent and wall Time/Temperature graphs, and subsequently 10 minute averaged temperature profiles.

6.1 Fire Growth and Development

6.1.1 Observations

Nearly all of the fires conducted in the experiments behaved in an identical manner in the growth and development phases. From piloted ignition with the torch, the fire initially burns as an open pool fire completely within the pan. The photo in Figure 6.1 shows this initial burning in the pan at the back of the compartment.

Figure 6.1 Initial state of burning.

The initial burning in the pan lasts momentarily, until all the oxygen within the compartment has been depleted. The plume and ceiling jet from the pool fire increases the interior compartment temperature to approximately 600-800°C. For the larger ventilation opening fires conducted in these experiments, the initial natural flame height exceeds the height of the compartment. This causes the flame to extend slightly across the roof as a ceiling jet, and thus contribute considerable heat to the ceiling which consequentially radiates back to the fuel. The occurrence of this flaming ceiling jet gives rise to higher compartment temperatures of about 800°C at this stage of the fire.

After the compartment oxygen has been depleted the inflow of air is insufficient to provide enough oxygen for full combustion within the pan. As the compartment temperatures rise, the production of pyrolyzates occurs at an increasing rate. At this point the combustion transfers from inside the pan, to burn in the localised vicinity around the pan where oxygen is able to penetrate.

As the production of pyrolyzates continues, this enlarges the amount localised burning around the pan and it fluctuates anywhere from the floor to the ceiling, depending upon the availability of oxygen. As the amount of burning taking place increases, more oxygen is required and the combustion zone progressively moves toward the front of the compartment to acquire this oxygen. This accumulation and growth continues for approximately 10-15 minutes depending on the size ventilation of the ventilation opening and temperatures achieved.

The combustion then goes through a transition, in which the flame front moves from the rear of the compartment, to the front. This intermediate stage involves the combustion oscillating forwards and backwards from the vent. This pulsing continues until an equilibrium is achieved and the flaming region becomes stable at the front opening. The photo in Figure 6.2 shows the flaming region reaching the front of the compartment.

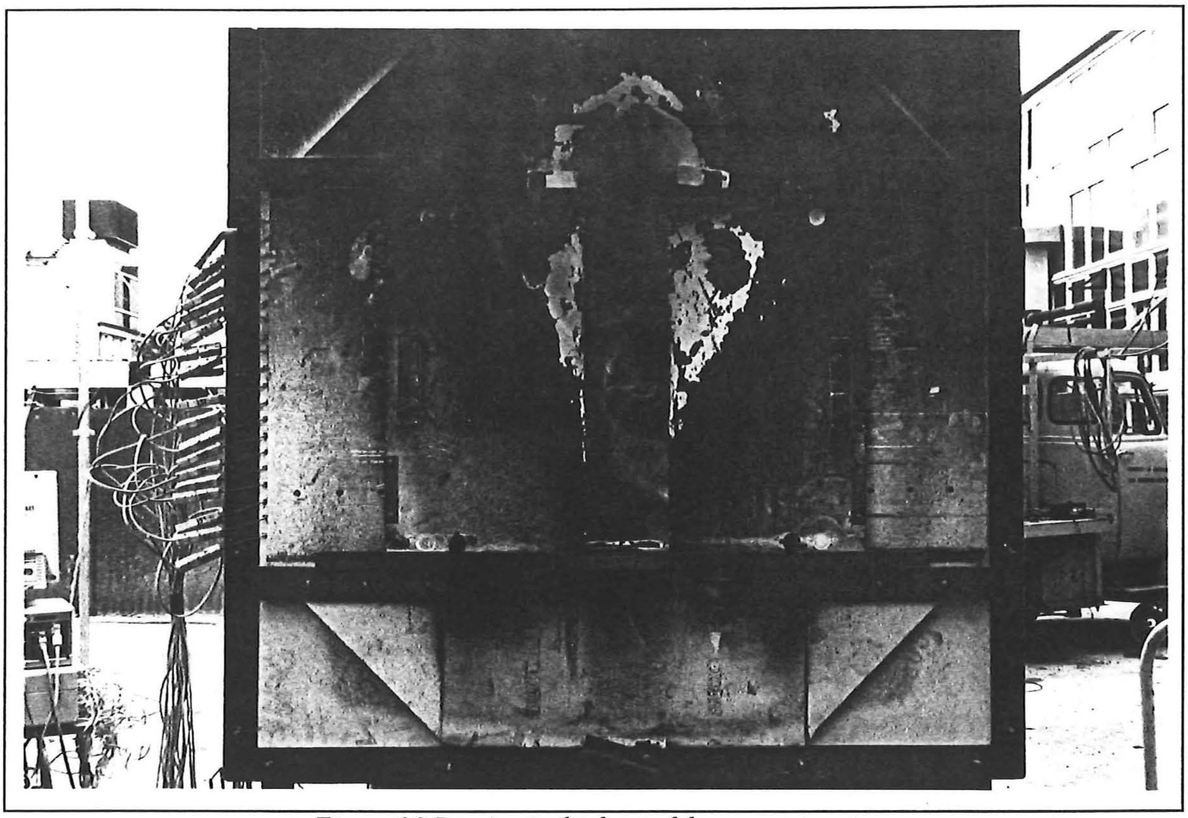

Figure 6.2 Burning in the front of the compartment..

After the combustion zone has reached the front of the compartment, it can be regarded that flashover has occurred. At this point the fire develops until flames extend out of the vent and burn continuously within the vent region. Figure 6.3 shows a photo of this continuous vent burning, with the photo in Figure 6.4 displaying a vent flame profile.

This burning is supported by the volatilisation of the fuel in the pan and develops to a maximum, as steady state is attained. Temperatures of up to 1000C are achieved in the flaming zone.

The temperatures achieved are of course dependent on the degree of ventilation. As the ventilation opening increases the amount of oxygen getting to the combustion zone increases. This results in an increase in the amount energy released and higher temperatures.

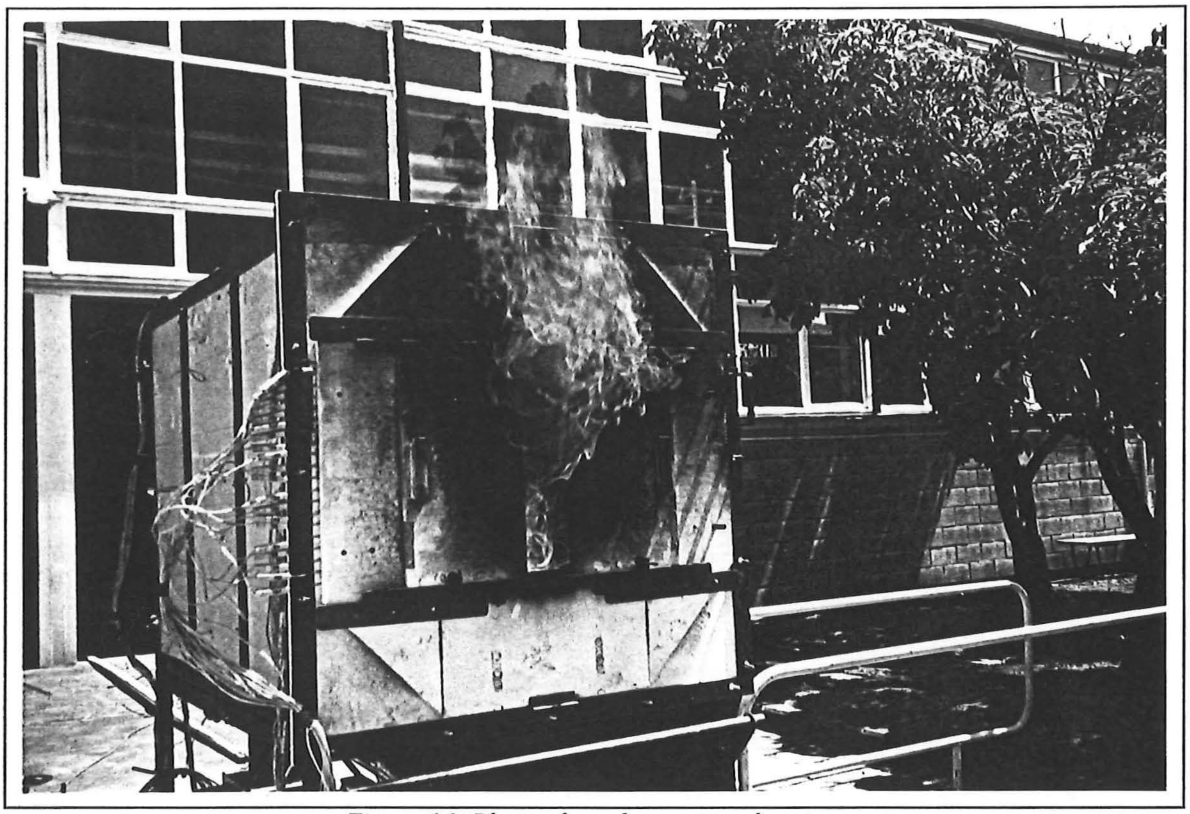

Figure 6.3 Photo of steady state vent burning.

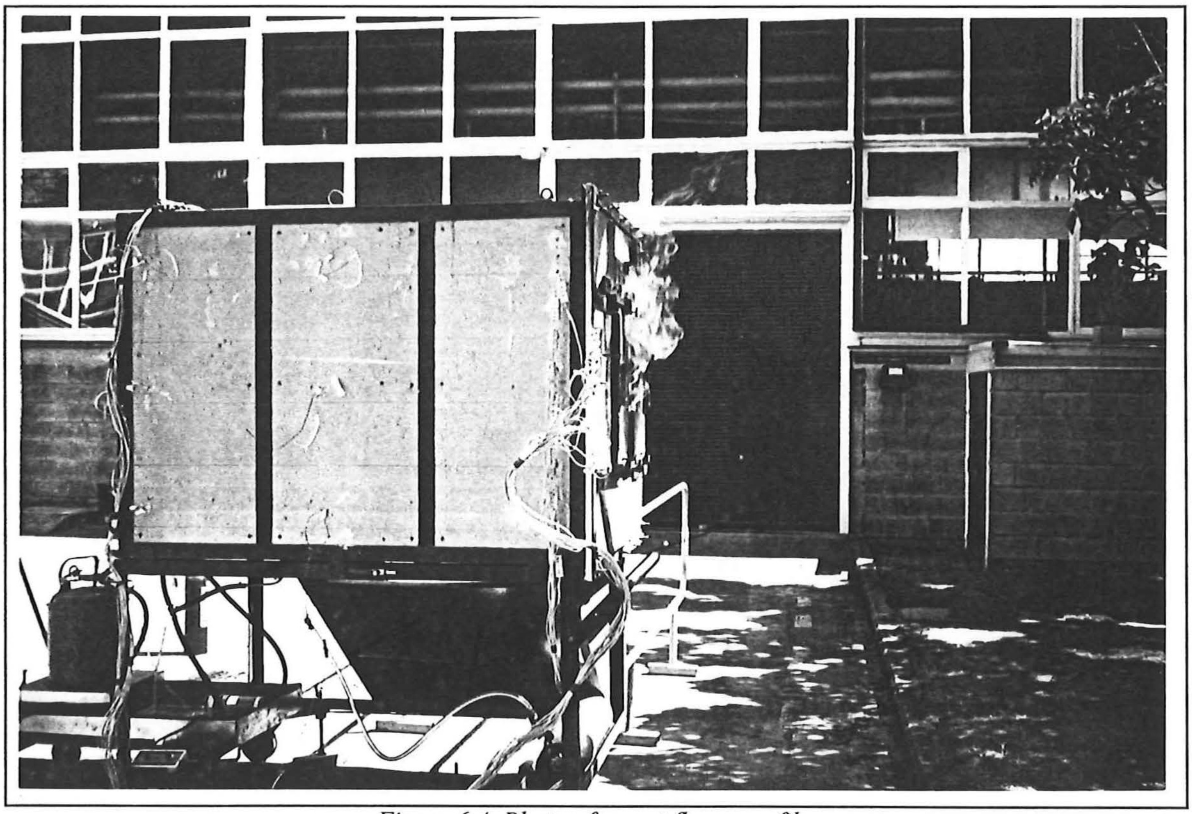

Figure 6.4 Photo of a vent flame profile.

Two experiments were conducted in which there was not sufficient ventilation for the fire to be allowed to grow. At this point, inadequate was ventilation caused the fire to self-extinguish.

One of the experiments repeated did not behave as per the others. The fire initially burned in the pan but reached a point where combustion seemed to have been extinguished. No visible burning could be seen in the compartment, but heat and increasing amounts of pyrolyzates were seen flowing from the vent. This self contained volatilisation continued for approximately one hour where temperatures of 600°C were achieved at the front of the compartment. At this point the gases in the front of the compartment ignited, through either pilot ignition from the back or by self ignition, and subsequently steady state sustained vent burning ensued.

The weather conditions did not play a major part in the control of the fire, with the wind speed on average being approximately 1.5 m/s. There was still some compartment leakage through the explosion panel, but this was covered with Kaowool and had a minimal effect. Carbon build-up occurred on thermocouples within the compartment and vent. It was more prevalent in the larger ventilation experiments, where deposits on successive vent thermocouples meet. Carbon was only significantly deposited on the upper thermocouples in a tree, but these deposits would have had an effect on the temperatures and vent flows.

6.1.2 Time/Temperature Graphs

The growth and development of these fires can also be seen in the temperature results obtained. Figure 6.5 shows the Time/Temperature curves at the rear of the compartment for one of the experiments conducted.. It can be seen in Figure 6.5, that the temperatures rise to a maximum at the rear of the compartment, followed by fluctuations due to the turbulent combustion around the pan. This is succeeded by pulsing, as the flame front oscillates to the front of the compartment. At this point the combustion has moved to the front, resulting in less turbulent temperature readings at the rear of the compartment.

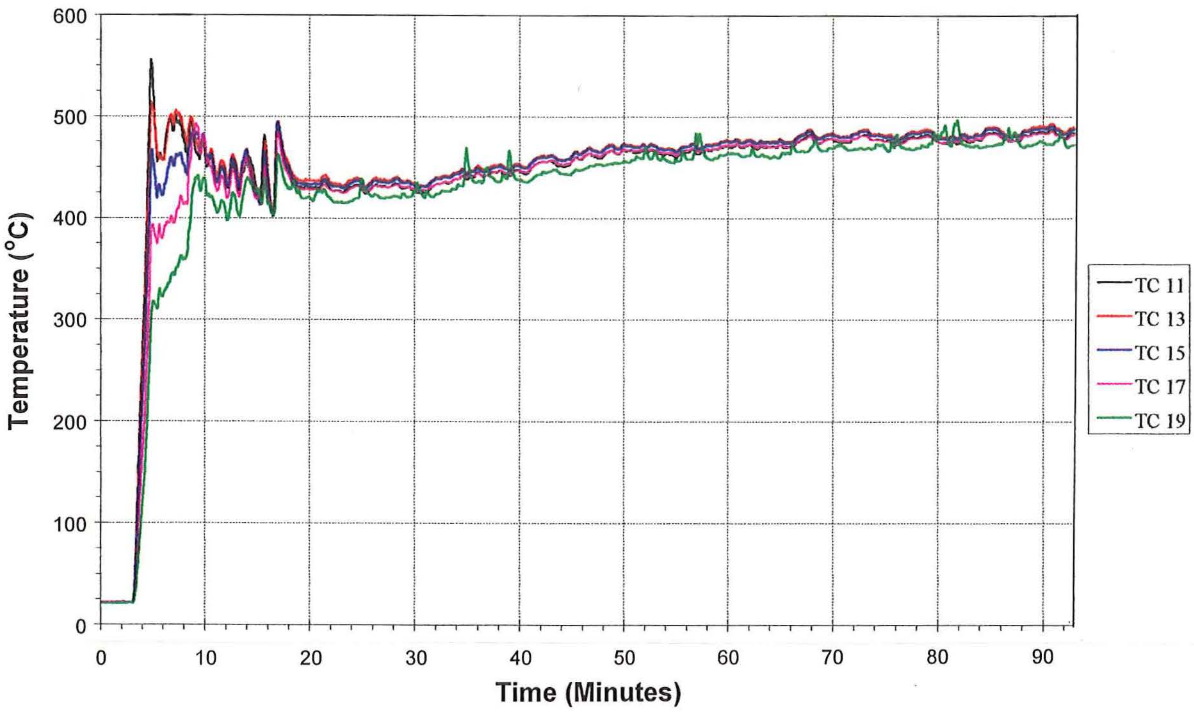

Figure 6.5 Time/Temperature curves at the rear of the compartment.

The opposite can be seen in the Figure 6.6, which shows the Time/Temperature curves at the front of the compartment. The temperatures build slowly, but attain a maximum as the flame front and combustion reaches the front of the compartment.

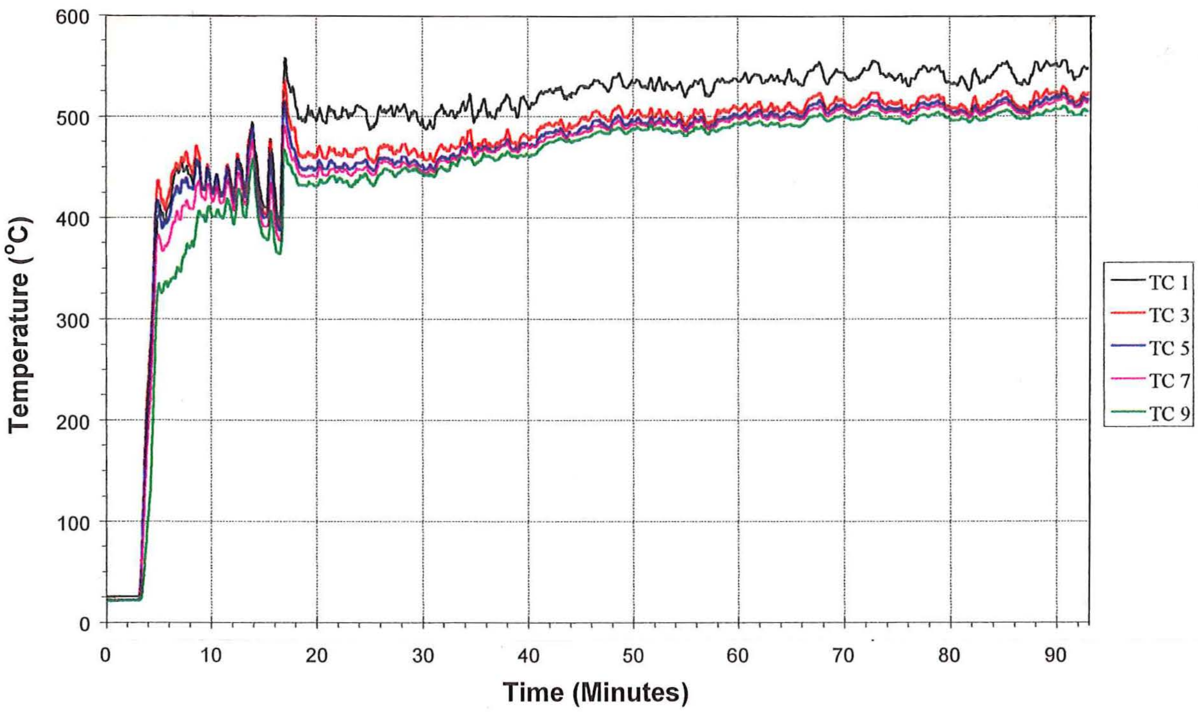

Figure 6.6 Time/Temperature curves at the front of the compartment.

Burning takes place both in the front of the compartment and in the vent, until finally the combustion region moves to within the vent only and a steady state is achieved. Figure 6.7 shows the Time/Temperature curves within the vent region, and it can be seen that burning takes place within the vent at approximately 18 minutes.

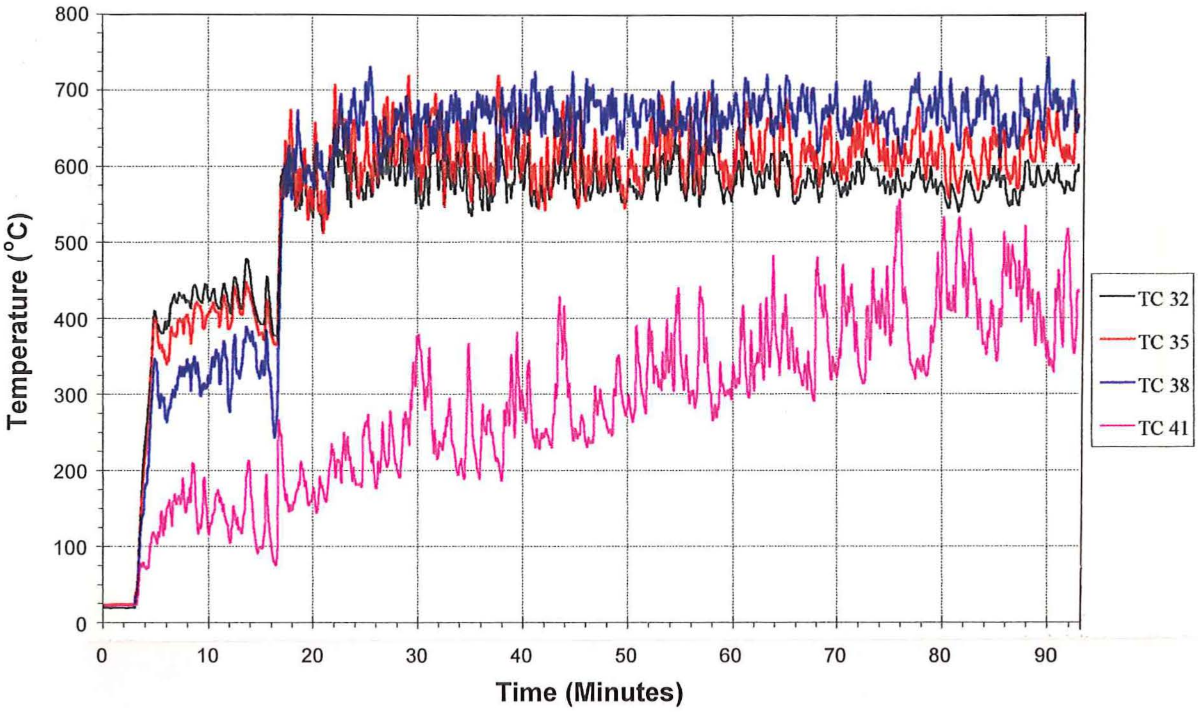

Figure 6.7 Time/Temperature curves in the vent.

6.1.3 Sustained Vent Burning

The sustained burning that takes place within the vent, once steady state burning has been achieved, is entirely fuelled by the volatilisation occurring in the pan at the rear of the compartment. Reducing the ventilation opening to below that in which the initial combustion would take place, does not promote the fire to self-extinguish. This can be seen in the Time/Temperature curves in Figure 6.8, in which an experiment was conducted where the ventilation was decreased to determine the effect upon the fire.

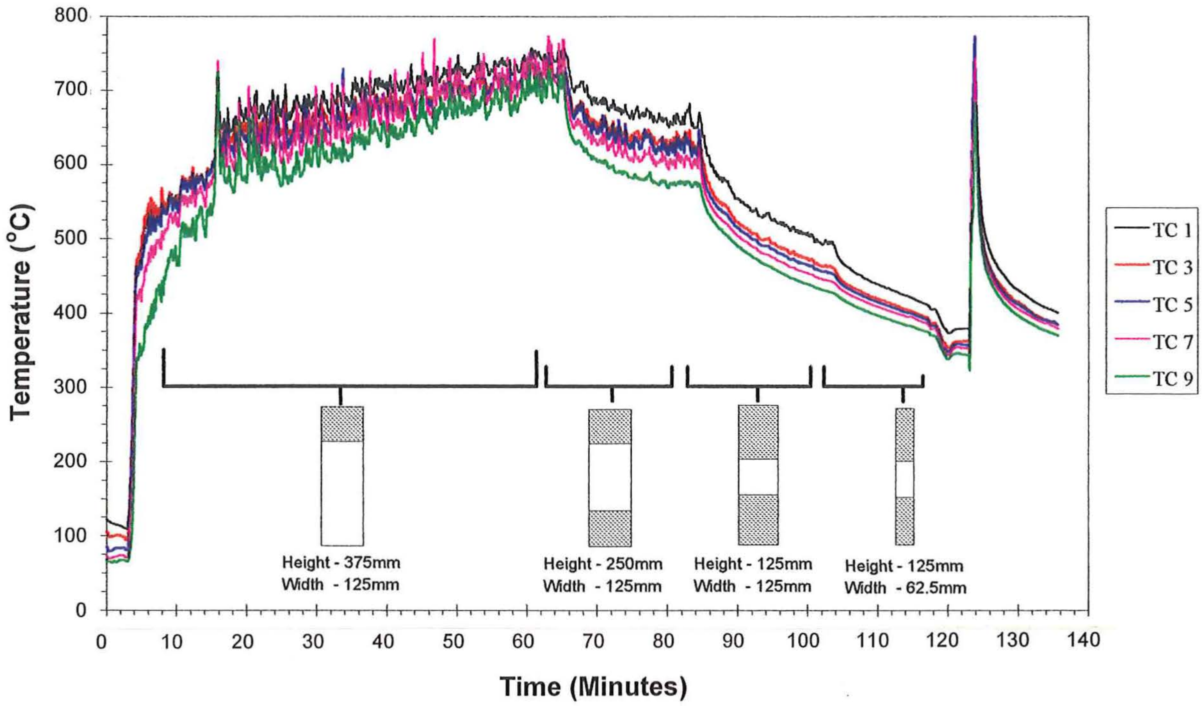

Figure 6.8 Time/Temperatures curves of changing ventilation.

Even once the vent panels had been full closed for extinguishment, the fire persisted with flames projecting through gaps between the door panels, as they grasped at any available oxygen. Only when a CO_2 extinguisher was used to put out these flames, did the flames go out. However, once the panels were opened approximately 5 minutes later a backdraft resulted, as seen by the sudden temperature rise at the end.

The occurrence of the backdraft was a surprise at the time, but as the auto ignition temperature of heptane in air is 223°C [11], its occurrence is not understandable.

6.2 Vent Flows

6.2.1 Temperature Profiles

As the fire begins burning in the back of the compartment, the ceiling jet grows, and hot gases accumulate at the ceiling. Figure 6.9 shows 10 minute averaged temperature profiles at the rear of the compartment for one of the experiments. The hot gases give rise to a hot upper layers, with a cooler layer below. This zoning can be seen in the 10 minute profile in Figure 6.9.

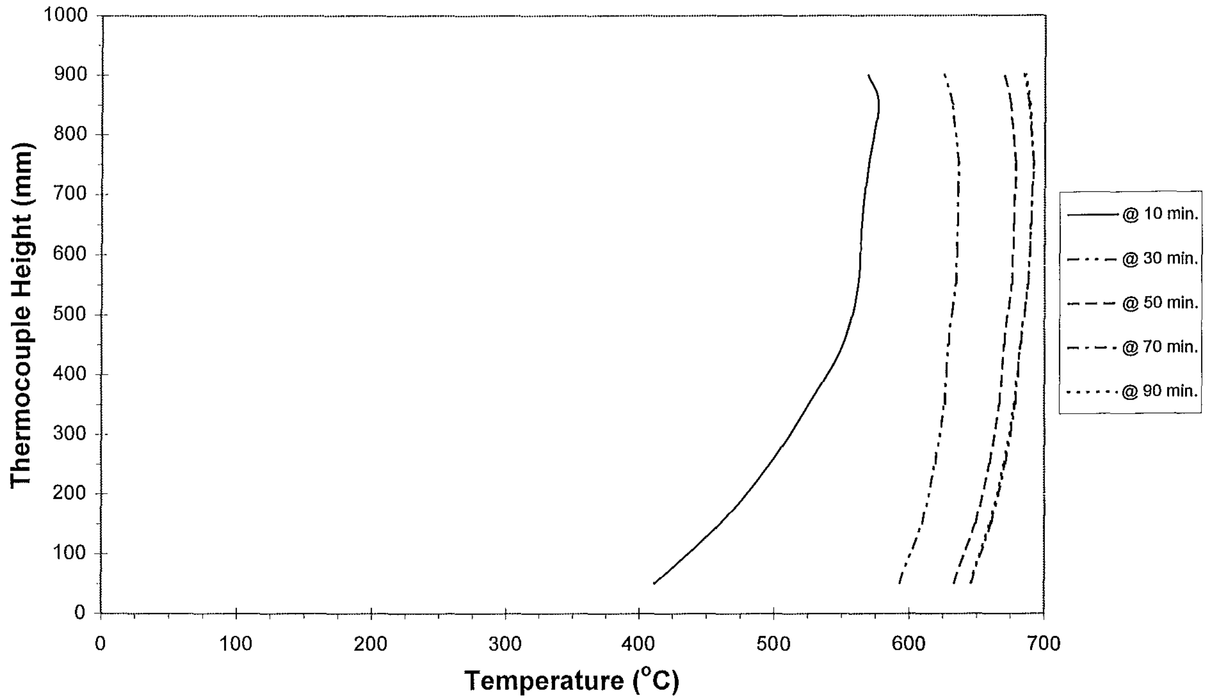

Figure 6.9 10 minute averaged rear temperature profiles.

However as time progresses, and the hot layer drops within the compartment, the definite distinction between the hot layer and cooler lower layer becomes less defined. This can be seen in the last 4 temperature profiles in Figure 6.9.

Figure 6.10 shows the 10 minute averaged temperature profiles for the front of the compartment. It can be seen in Figure 6.10, that the profiles also behave in the same manner as for the rear of the compartment, in that there is no defined upper layer or lower layer region.

In this case it is also noticed that the ceiling jet has a pronounced effect on the temperatures recorded at the front. The temperature profile spikes at the location of the very top thermocouple. This reflects the heat of the ceiling jet as well as some possible turbulence of the flames in the vent.

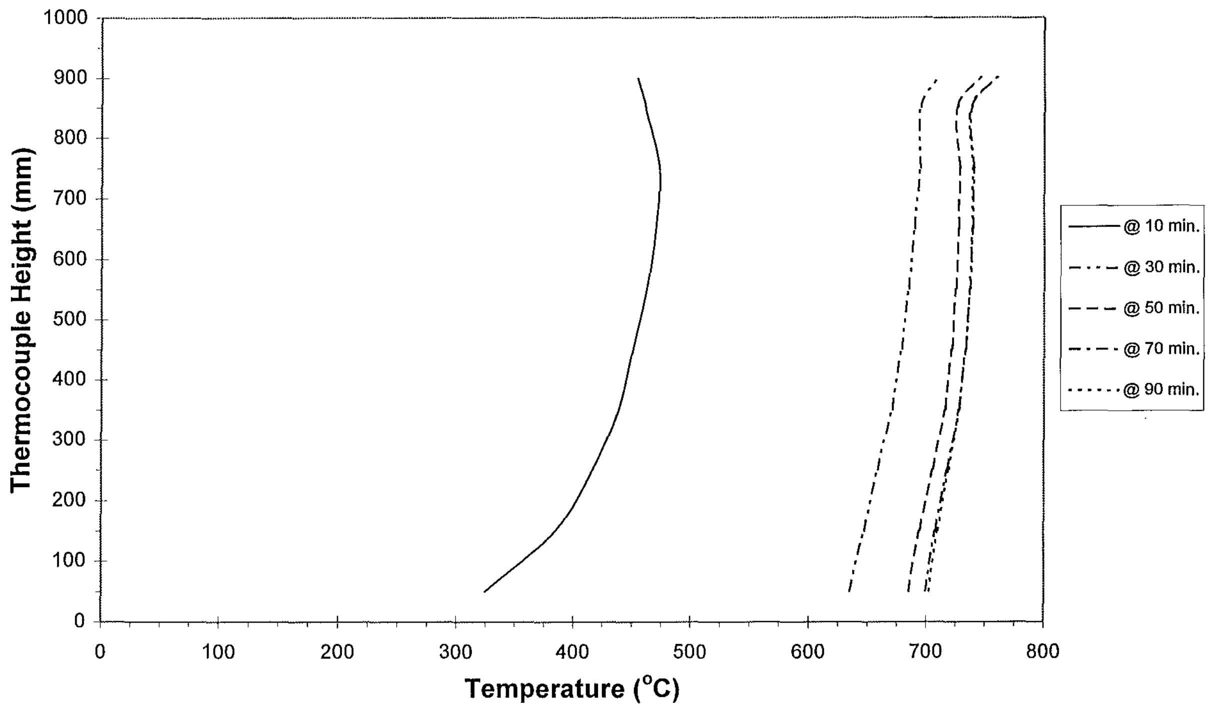

Figure 6.10 10 minute averaged front temperature profiles.

Figures 6.11 and 6.12 show the vent temperature profiles obtained in two different experiments. The close spacing of the thermocouples in the tree, gave very detailed temperature profiles (see Figures 6.11 and 6.12).

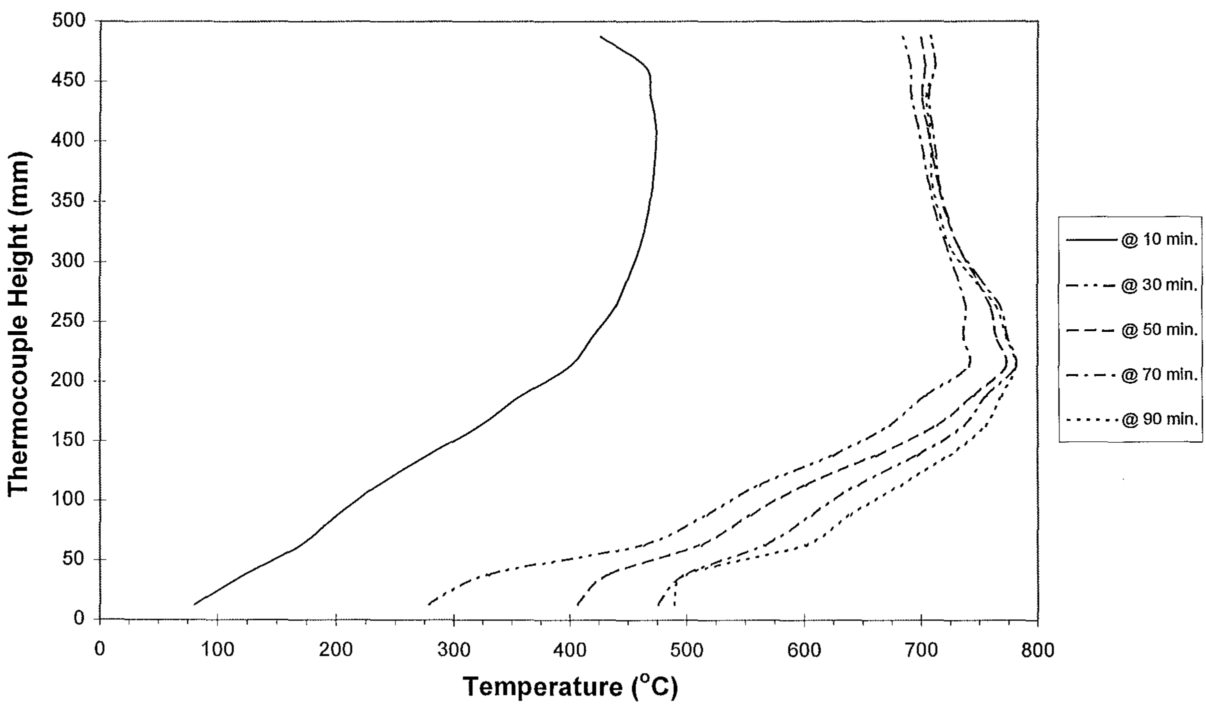

Figure 6.11 10 minute averaged vent temperature profiles.

Consistent profiles were obtained between each successive temperature profile in the latter half of the experiment, indicating that a near steady state condition had been achieved.

In the later stages of the fire, the flames extended out of the vent at approximately mid height, bypassing contact with the upper thermocouples. This results in hot temperatures in the centre of the door and cooler above (see Figure 6.11).

Figure 6.12 shows the vent temperature profiles obtained in an experiment conducted with the lower door panel raised. Flaming combustion built up behind this panel and affected the lower thermocouple readings. This can be seen in Figure 6.12, where the bottom thermocouple temperature is significantly higher than the adjacent thermocouple above.

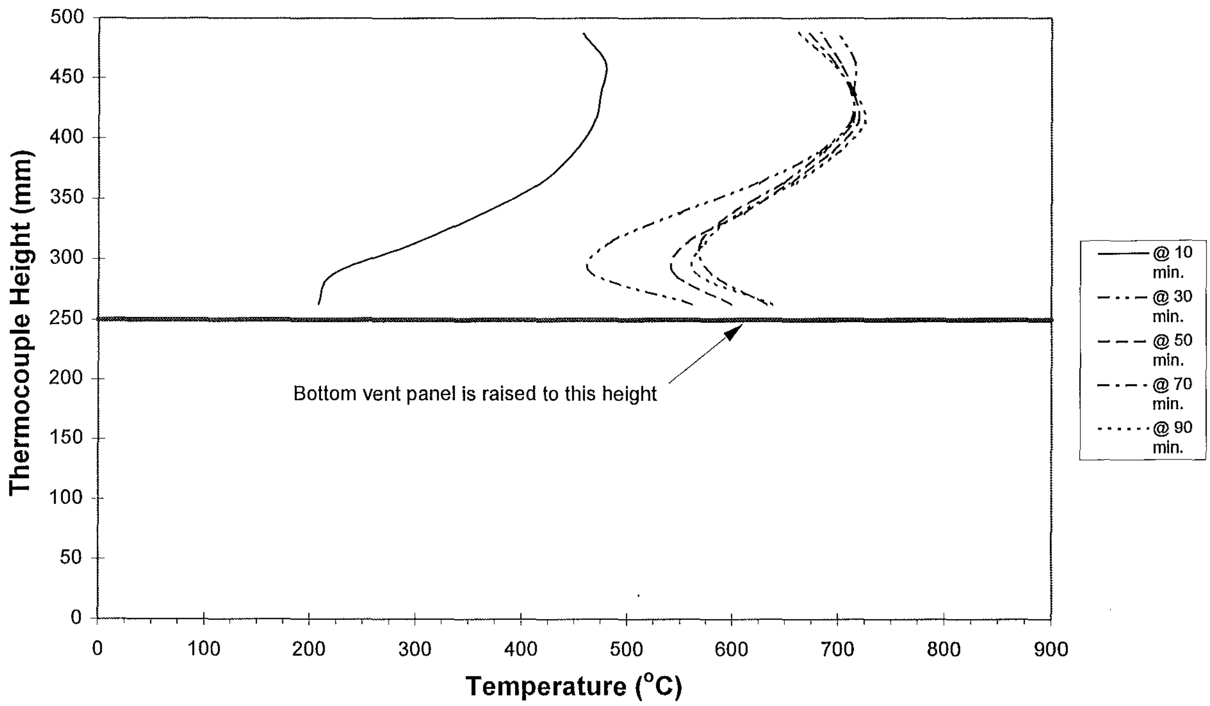

Figure 6.12 10 minute averaged vent temperature profiles with bottom panel raised.

6.2.2 Neutral Plane

The neutral plane height for each experiment was calculated from the numerical iteration of Equation 5.4. Figure 6.13 shows the layer heights obtained for each experiment and subsequent ventilation opening, with the bottom of the door as a reference point. It can be seen that if the top door panel is lowered, the neutral plane follows. However, for a set ventilation height, a reduction of the vent width has little effect on the neutral plane location.

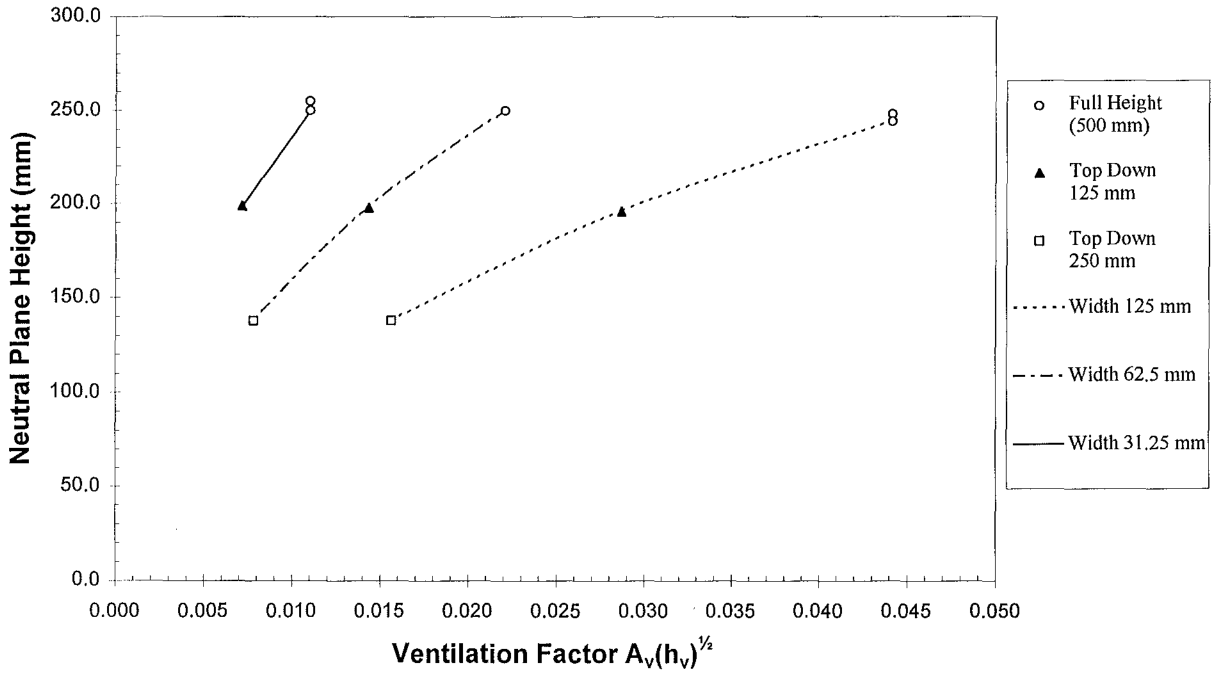

Figure 6.13 Neutral plane heights.

However if the neutral plane location is analysed with respect to the height of the different vent opening used, it is seen that the neutral plane is located approximately at mid height of the opening. This can be seen in Figure 6.14 where a non-dimensionalised neutral plane factor, of the height of the neutral plane over the height of the door opening, is plotted against the ventilation factor.

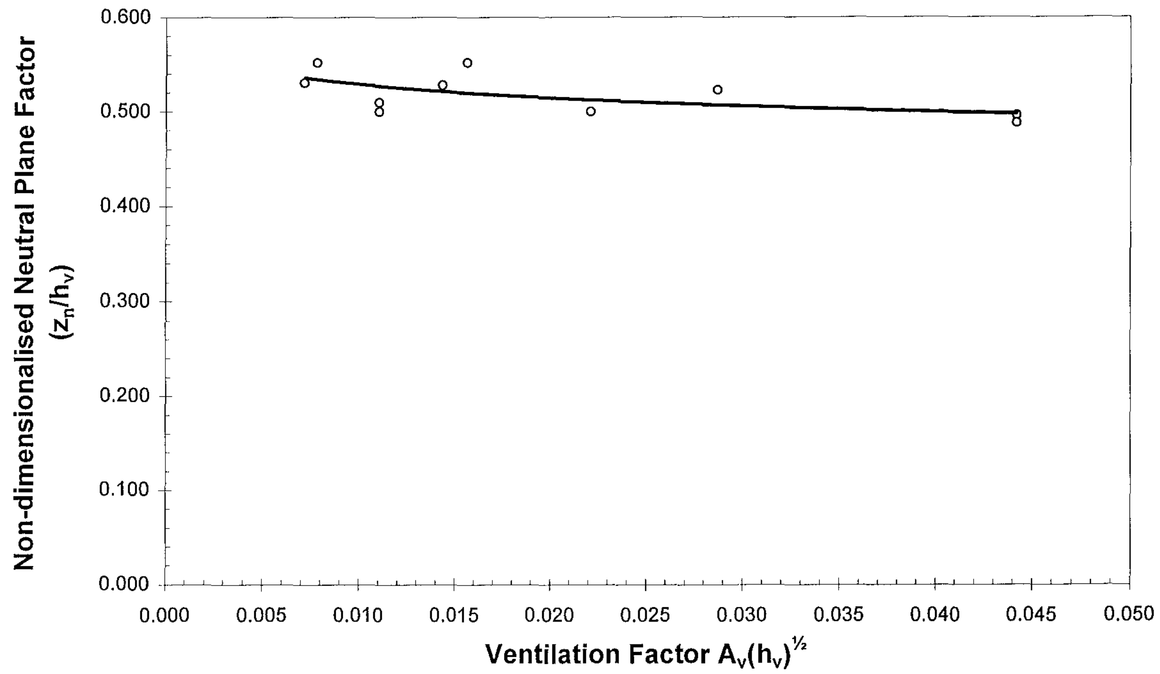

Figure 6.14 Non-dimensionalised neutral plane factor.

This would suggest that the mass flow rate through the vent increases or decreases uniformly, keeping the neutral plane location at the middle of the vent opening.

6.3 Fuel Mass Loss

The most significant findings were those related to the fuel mass loss.

Figure 6.15 shows the mass loss rates for each experiment plotted against their corresponding ventilation factor. A good relationship was achieved between the experimental mass loss data, as can be seen in Figure 6.15. Comparison of the compartment results and of those obtained in the experimental free burning fire, to empirical equations in Chapter 5, found the following points which can be seen in Figure 6.15.

- The free burning pyrolysis rate was found to be greater than that of the empirical correlation.

- The mass loss rate achieved within the compartment is higher than the mass loss rate available to stoichiometric ventilation controlled burning.

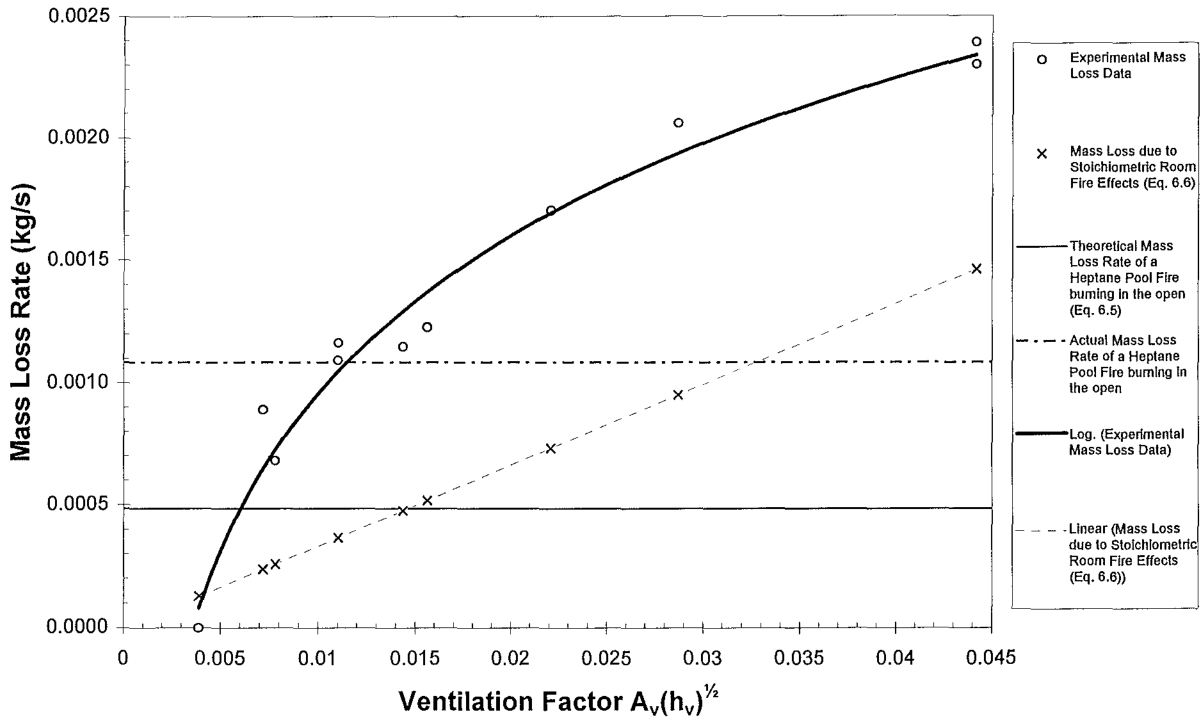

Figure 6.15 Mass loss rate comparisons.

From these comparisons, it can be seen that the fire does not become ventilation limited until the free burning fire pyrolysis line crosses the stoichiometric room fire pyrolysis line, at a ventilation factor of approximately 0.033 . However the mass loss rate actually obtained in the experiments exceeds both the free burning mass loss rate and the stoichiometric compartment mass loss rate quite dramatically. Figure 6.16 shows the difference between the experimental and correlation lines, given a factor of actual amount of fuel burned, compared to that which can be theoretically burned within the compartment.

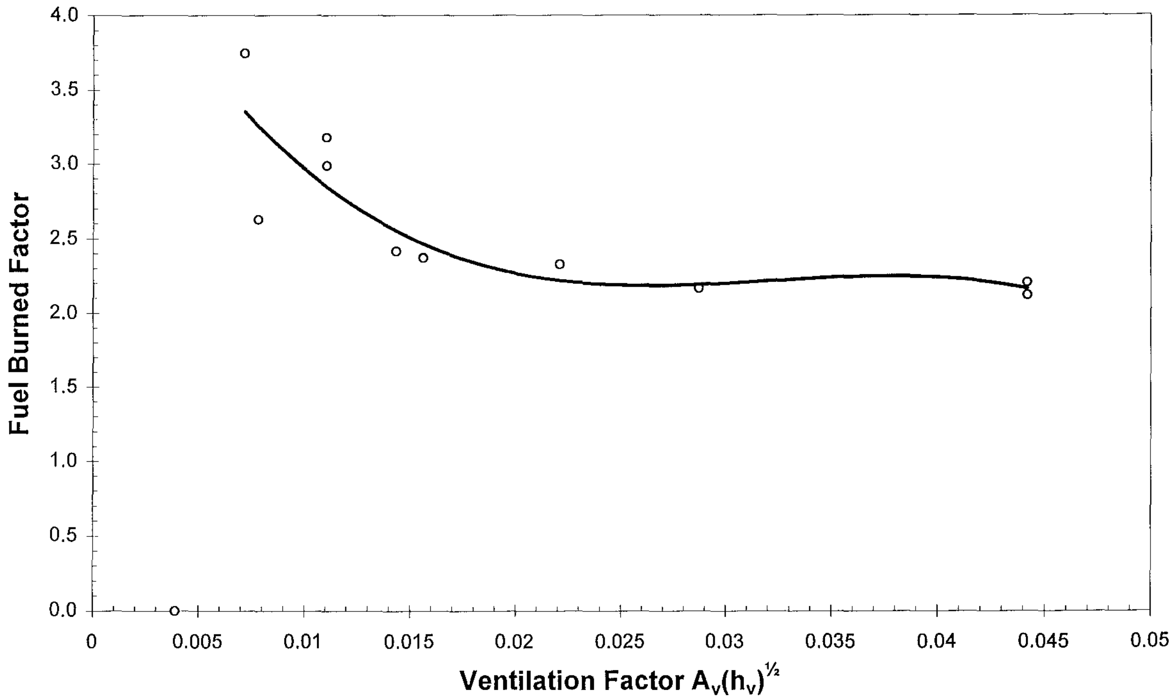

Figure 6.16 Fuel burned factor.

So it can be seen from this comparison, that in the experiments we were burning up to approximately 3.5 times the amount of fuel in the compartment than the available ventilation would allow. Figure 6.16 also shows that a fuel burned factor of approximately 2.1 occurs up to a ventilation factor of 0.025, at which point it increases. This would suggest that the compartment fires become ventilation limited at a ventilation factor of approximately 0.025.

An experiment was also carried out with the lower door being raised. This was compared to the experiment conducted with the top door panel being lowered by the same amount. The mass loss rates obtained were found to be nearly identical, which supports the correlations of the ventilation effect on the pyrolysis rate.

6.4 CFAST Results

The results from CFAST (see Appendix E.) were compared with those obtained in the experiments. In all the cases the model predicted burning outside of the compartment. As CFAST is a two zone computer model, a layer height was calculated with upper and lower layer temperatures. As seen in 6.2.1, only a single layer was found to occur in the experiments, although CFAST did model the layer height to drop almost immediately to the floor. Temperatures well in excess of those attained in the experiments were achieved. Figure 6.17 below, shows a comparison of the upper and lower layer temperatures obtained from CFAST, to the average temperatures achieved at the front and back of the compartment in the experiments. The CFAST temperatures were taken at a time of 3000 seconds, as this corresponds to steady state time in the experiments.

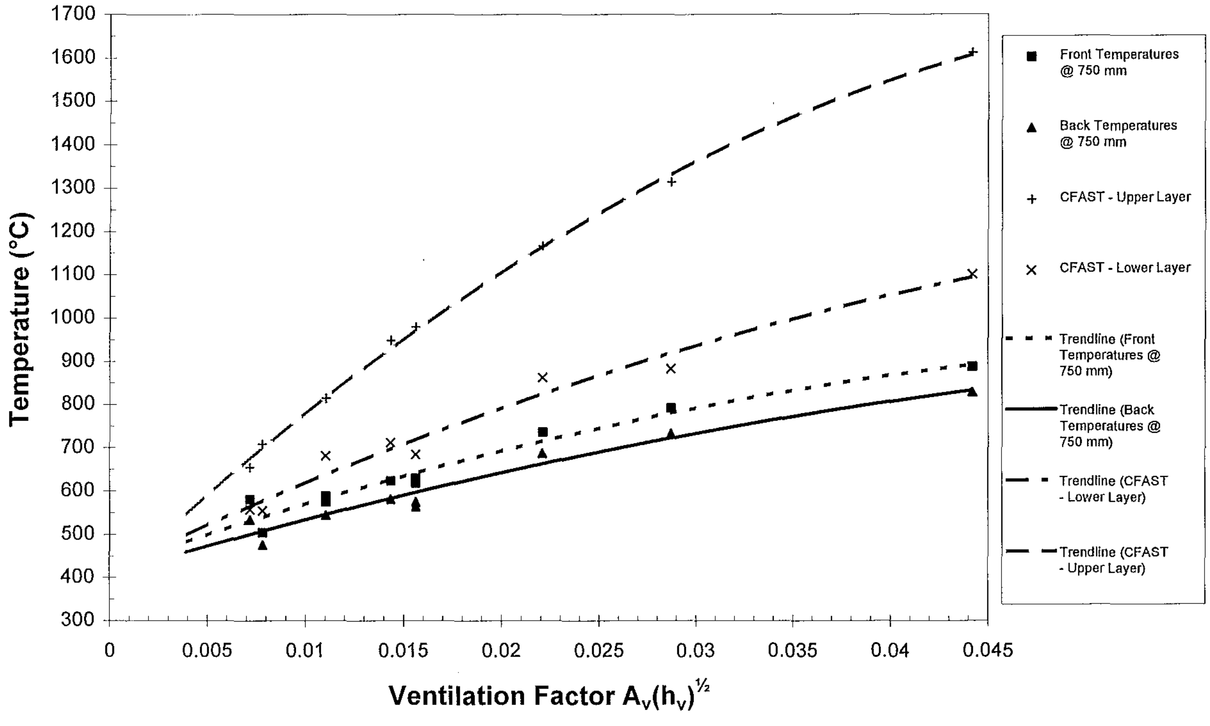

Figure 6.17 Temperature comparison between CFAST and experimental results.

The lower layer temperatures are closer to those achieved in the experiments but still overestimate by up to 200°C.

It can be seen then, that in this respect CFAST does not model the experiments well.

Chapter 7. Conclusion

- The initial compartment lining material of PROMATECT® H, did not perform well when repeatedly exposed to fires. The PROMATECT® H board has a negative coefficient of expansion, and furnace testing found that although the board contracts when heated, the rate of contraction increases as the board cools.

- All the fires conducted in the experiments were supplied with minimal oxygen, and all produced excessive quantities of unburnt fuel. The experiments conducted obtained compartment burning rates that were higher than expected, and higher than available ventilation would allow.

- Once steady state burning is achieved, no degree of ventilation reduction, except full sealed closure, will result in the extinction of the fire. The fire occurring at this stage is fully fuelled from the volatilisation of the liquid pool at the rear of the compartment. This is due to the radiative feedback off the compartment walls, diffusion flame and gas layer.

- The compartment fires become ventilation limited at a ventilation factor of approximately 0.025. Before becoming ventilation limited the mass loss rate is approximately twice that than expected due to the available ventilation.

- Once the compartment has reached a ventilation limited state, the mass loss within the compartment increases. As the size of the ventilation opening is reduced, the amount of fuel burned to that available by the ventilation rises to a maximum of approximately 3.5, before the point of extinction is found.

- The neutral plane layer was found to be located at approximately the mid height of the opening for all of the experiments. Little effect was noticed due to a change in the width which suggest that the mass flows in and out of the compartment increase uniformly.

- In the initial stages of the fire, a definite upper hot layer and lower cooler layer can be seen in the temperature profiles. However as time progresses, and the hot layer drops within the compartment, no defined upper layer or lower layer region can be seen.

- CFAST did not model the experimental compartment fires well. It is a two zone computer model which calculates a layer height and upper and lower layer temperatures. In the experiments only a single layer was found to occur and CFAST calculated temperatures well in excess of those attained in the experiments.

Chapter 8. Further Research

The experiments undertaken in this report were limited by the complications that arose with the compartment materials. Further investigation is needed to understand the phenomenon of smoke explosions in a more stable compartment environment. The following are recommendations to add further research.

- The PROMATECT® H Board should not be used in repeated testing, due to is contraction and bowing side effects. However, the Kaowool compartment layout used in the final experiments, provides excellent insulation for very high temperatures and is recommended.

- Emphasis should be place on the smaller ventilation openings, in which the pyrolysis rate in the compartment grew substantially. This involves conducting experiments in the ventilation factor range less than 0.025, to gain a better representation of the mass loss at these smaller ventilation sizes. In doing so the point of extinction can also be pinpointed more accurately. These experiments should also be repeated using different pan sizes, to determine the effects from a change in fuel source size.

- Aspirated thermocouples should be include in the compartment instrumentation to gain a better values for the gas temperatures.

- Due to the small ventilation openings used in the experiment, visual observation of the combustion process and flame movement in the front of the compartment was limited. A window should be placed at the front of the compartment in which the combustion process in the front and vent can be witnessed.

- Gas analysis should be undertaken in the experiments to determine the fuel and oxygen concentrations inside the compartment. Sampling ports should be located at the front and back of the compartment. This would allow an analysis of the gases as the fire moves from the back of the compartment to the front.

- Weather conditions effect the behaviour of fire. If possible these experiments should be conducted in a controlled environment, to give consistent results.

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Appendices.

A. Material Properties.

B. Results from Initial Experiments.

C. Results from Furnace Tests on Promatect® H.

D. Experimental Results.

E. CFAST Results

Appendix A. Material Properties

A1. Specifications of Promatect® H.

A2. Specifications of Fire-Lite, Fire Rated Glass.

A1. Specifications of Promatect® H.

Note: All Specifications for 20 mm Board Thickness.

1. General Technical Data.

Properties	Promatect® H
Neutral designation	Calcium silicate (asbestos-free)
Material class	non-combustible acc. to DIN 4102, BS 476 Pt 4
Surface spread of flame	class 1 to BS 476, Part 7
Building regulations classification	class 0 to BS 476, Part 6
Raw density	approx. 900 kg/m³
Thermal conductivity	approx. 0.23 W/mK
Alkalinity (pH value)	approx. 12.0
Diffusion resistance factor	approx. 20
Moisture content (air-dried)	approx. 7%
Water absorption capacity	approx. 0.55 g/cm³
Expansion when under water, 100% saturation	max. 0.5 mm/m
Length and widths tolerances of standard boards	± 5 mm
Thickness tolerances of standard boards	± 0.5 mm
Coefficient of expansion	-6.4×10^{-6} m/mK (20-600°C)

2. Format, weight, heat insulation.

Standard format, mm	Board weight, kg/m² (approx)		Thermal resistance m² K/W	Heat transition coefficient k W/m² K
	Dry weight	Weight with approx. 6% moisture (min.)		
2440 x 1220	18.0	19.1	0.114	3.61

3. Static Values.

	Promatect® H
Modulus of elasticity E	
Longitudinal	3200 N/mm²
Transverse	2500 N/mm²
Flexural strength $F_{rupture}$	
Longitudinal	10 N/mm²
Transverse	5.5 N/mm²
Tensile strength $T_{rupture}$	
Longitudinal	5 N/mm²
Transverse	4 N/mm²
Compressive strength	8 N/mm²

A2. Specifications of Fire-Lite, Fire Rated Glass.

1. General Technical Data.

Characteristics	FireLite*
Thickness in mm (nominal)	5.0
Weight (approx. lbs./sq. ft)	2.5
Visible Ray Transmission	76.9
Visible Reflection	7.0
Bending Strength kg/cm² (average)	710
Hardness (Moh's Scale)	7.0

* Figures are for polished "Premium" Firelite.

FireLite is available in sizes up to 36″ x 96″.

Appendix B. Results from Initial Experiments

B1. Results from Phase 1 Experiments.

- Test #1
- Test #2
- Test #3

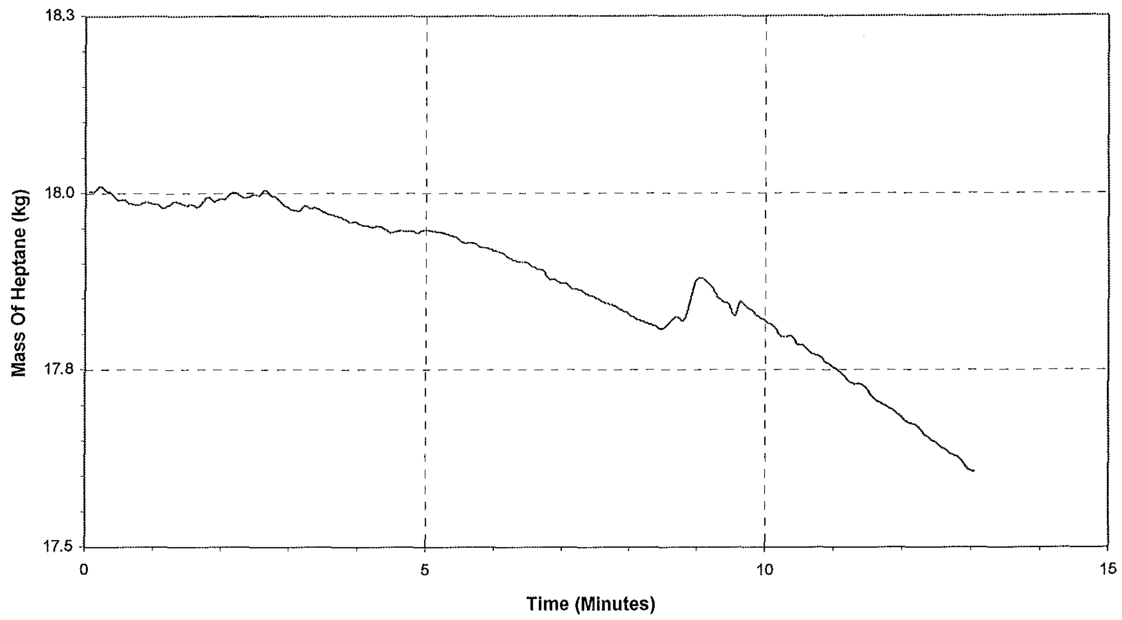
B2. Results from the Phase 2 Experiment.

B3. Results from the Phase 3 Experiment.

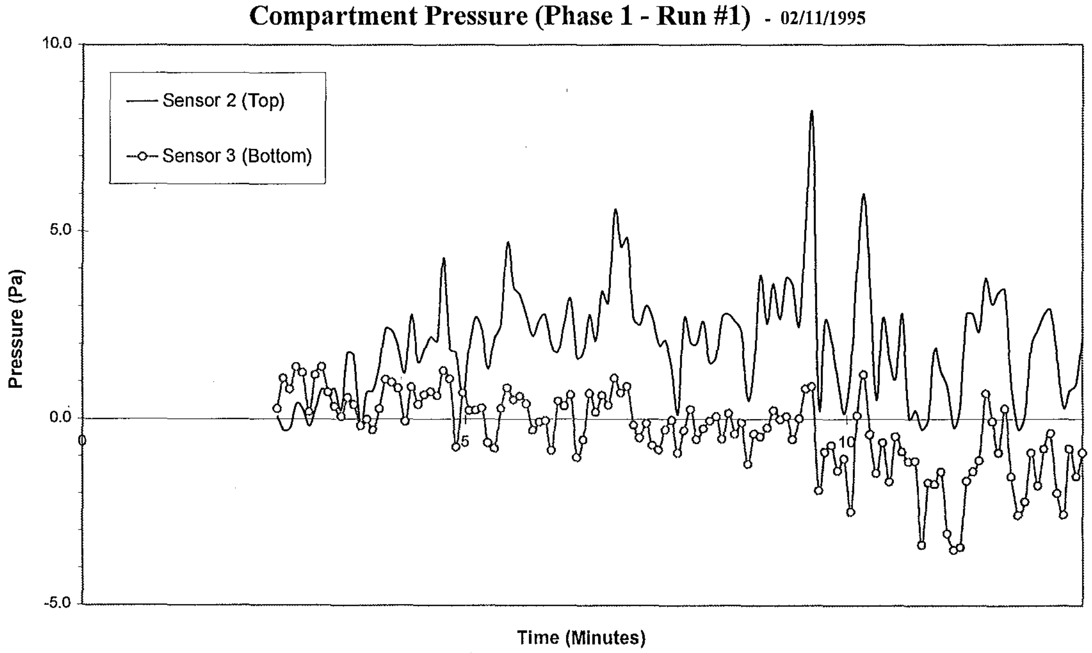
B1. Results from Phase 1 Experiments.

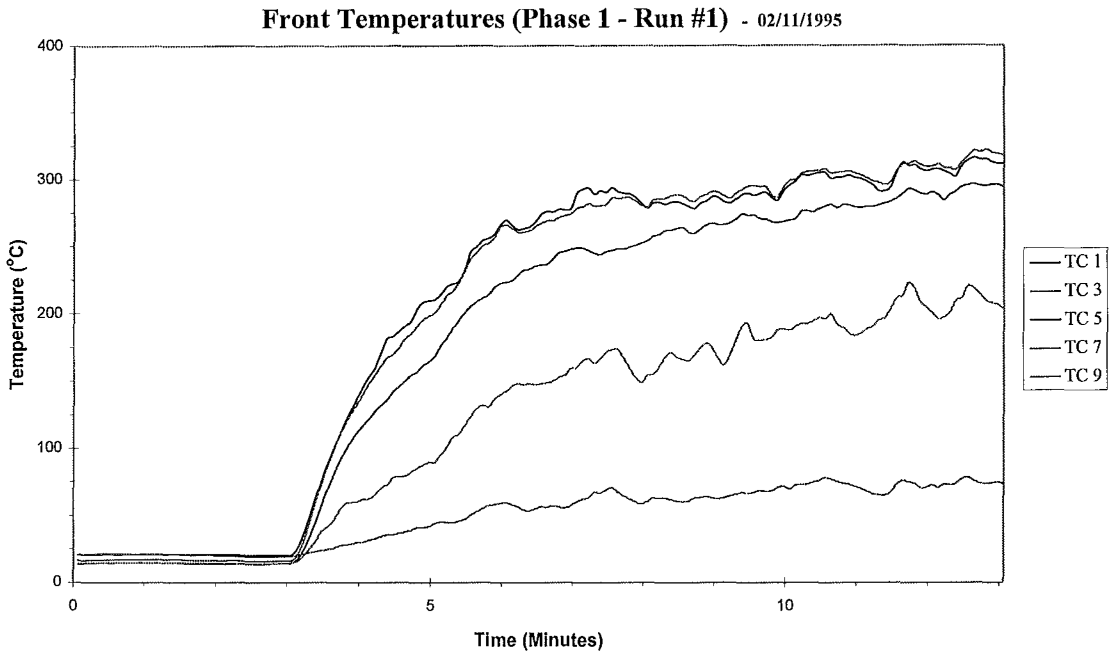
- Test #1

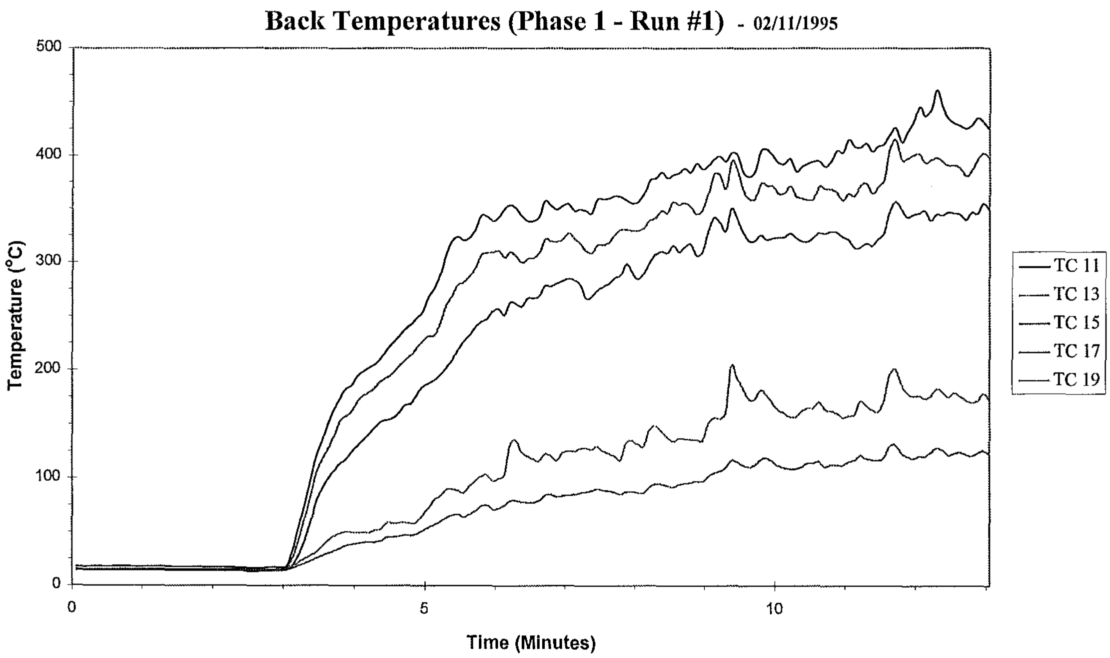
Heptane Mass Loss (Phase 1 - Run #1) - 02/11/95

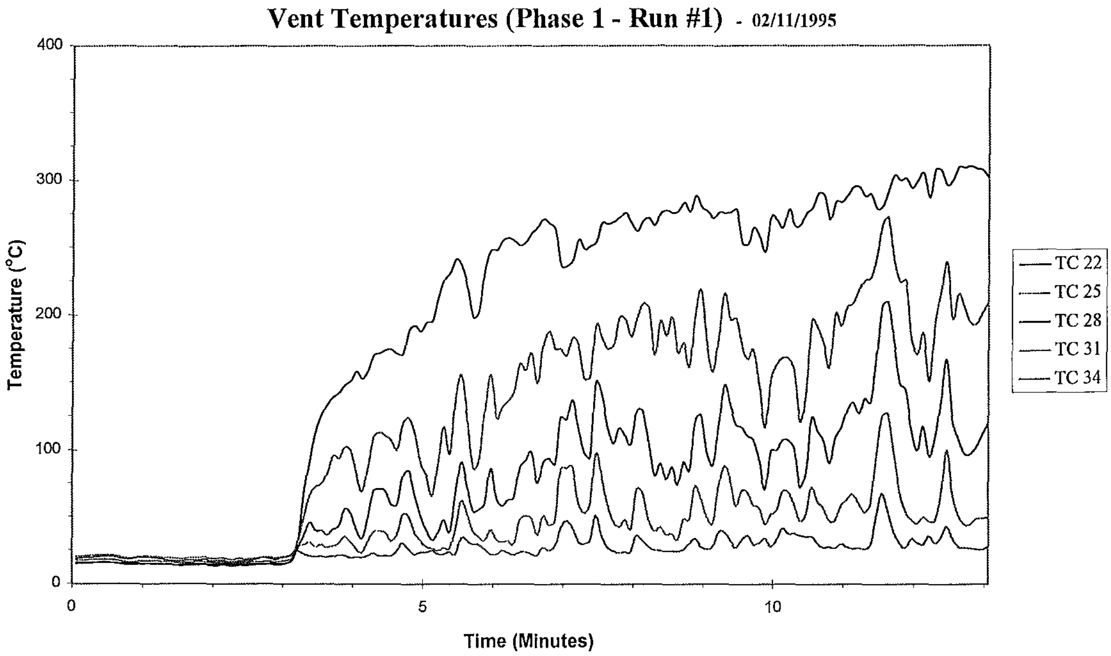


Compartment Pressure (Phase 1 - Run #1) - 02/11/1995



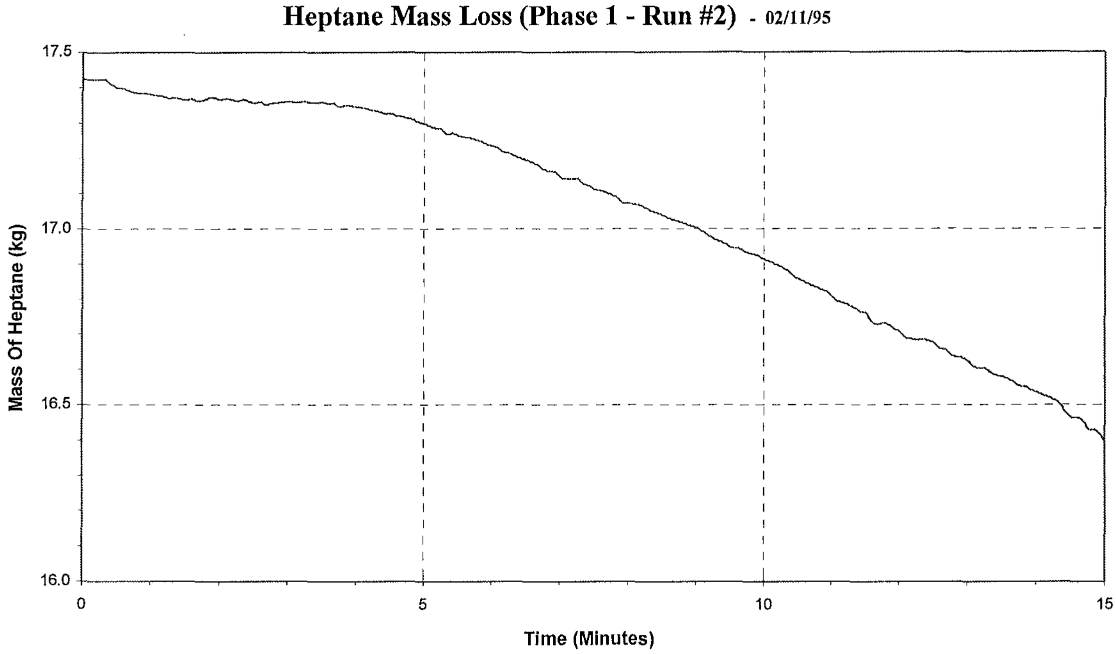

Front Temperatures (Phase 1 - Run #1) - 02/11/1995
400
300
200
100
0
0
5
10
Temperature (°C)
Time (Minutes)
TC 1
TC 3
TC 5
TC 7
TC 9

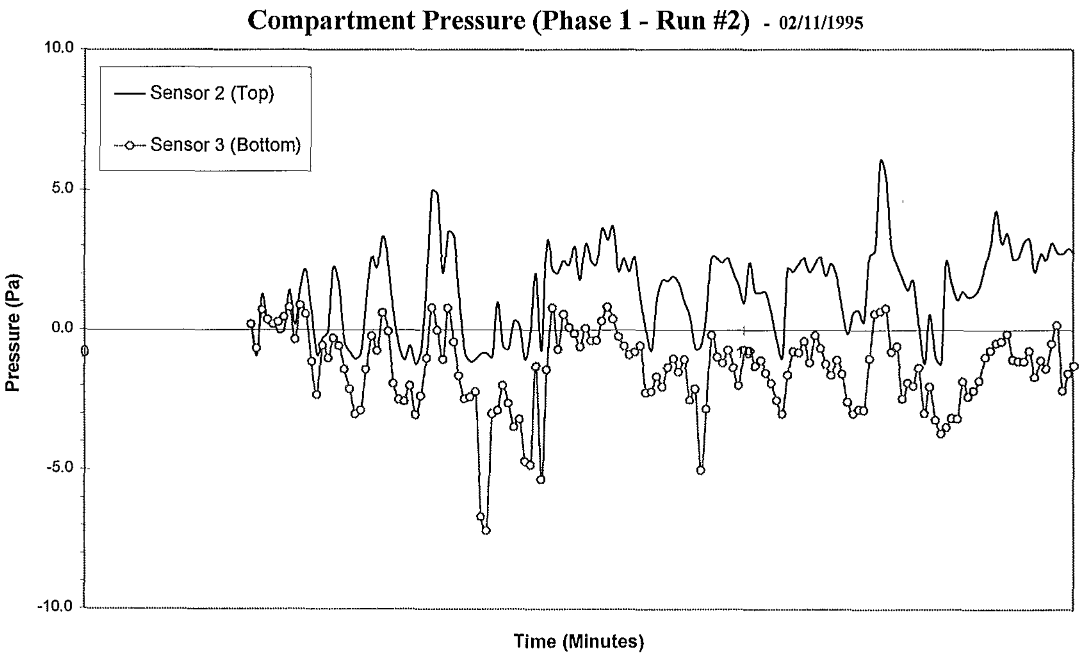

Back Temperatures (Phase 1 - Run #1) - 02/11/1995
500
400
300
200
100
0
0
5
10
Temperature (°C)
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19

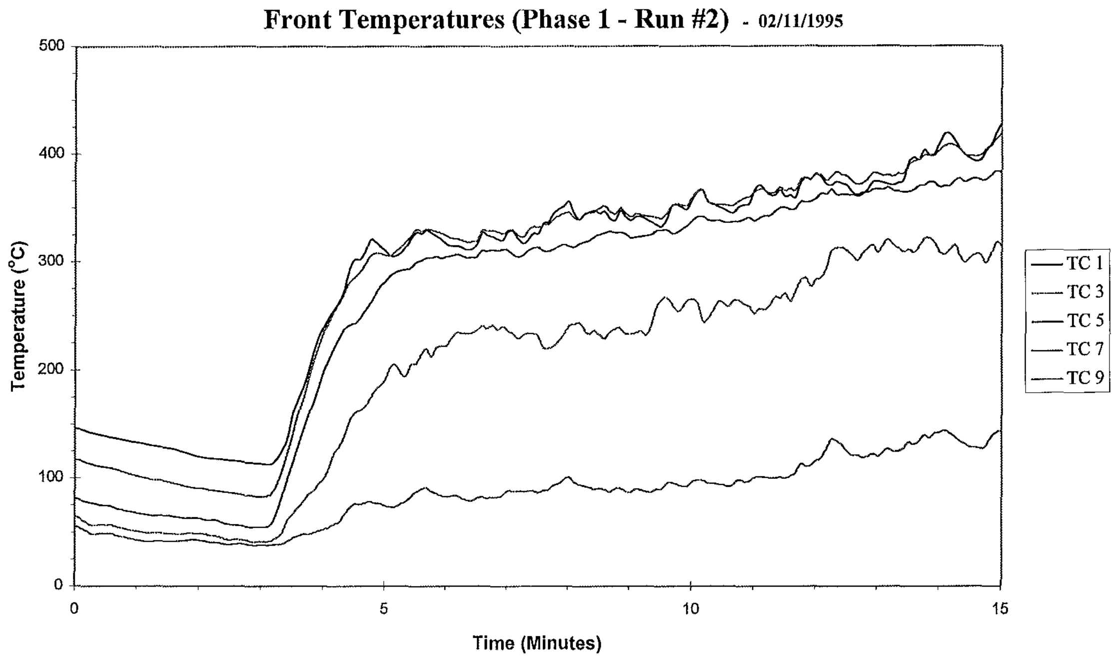

Vent Temperatures (Phase 1 - Run #1) - 02/11/1995
400
300
200
100
0
Temperature (°C)
0
5
10
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34

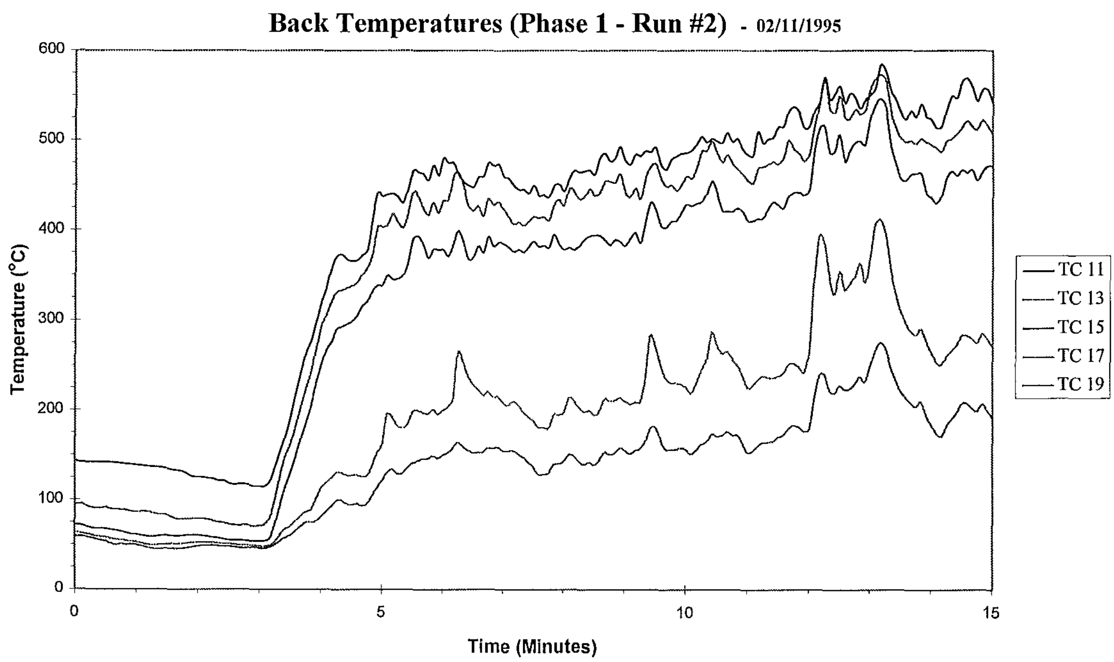
B1. Results from Phase 1 Experiments.

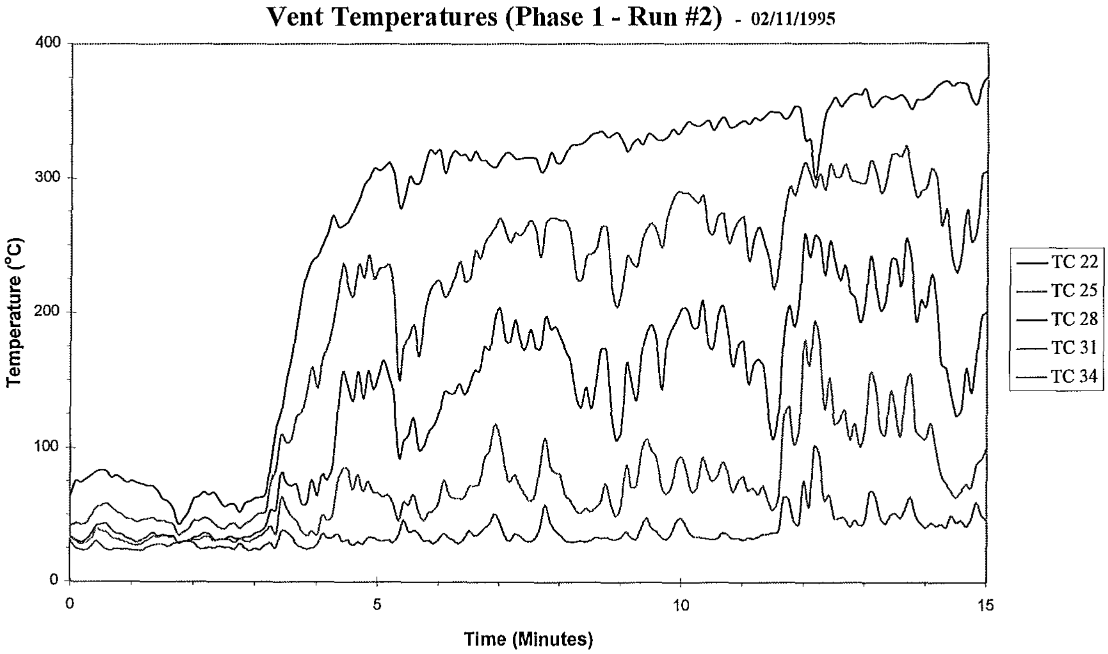
- Test #2





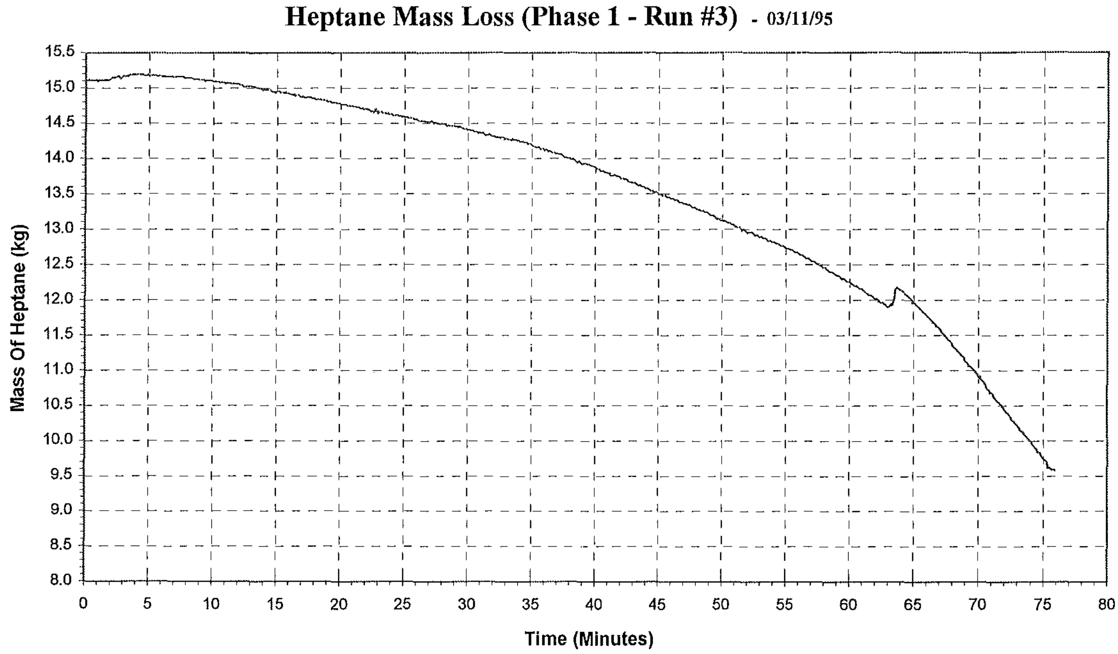

Front Temperatures (Phase 1 - Run #2) - 02/11/1995
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
0
5
10
15
TC 1
TC 3
TC 5
TC 7
TC 9

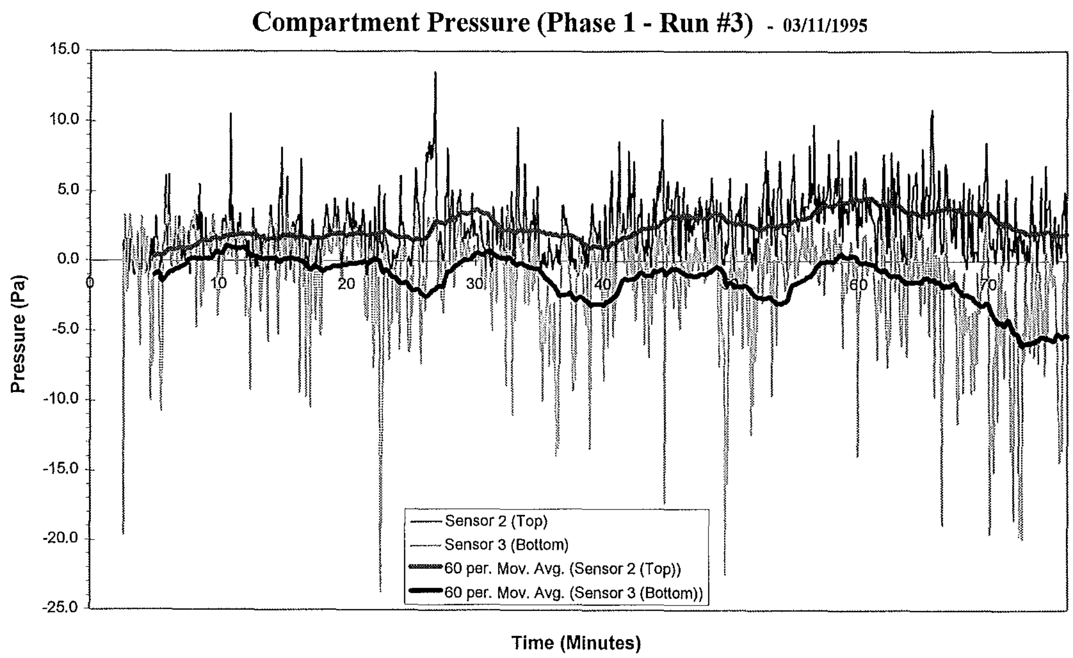

Back Temperatures (Phase 1 - Run #2) - 02/11/1995
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
600
0
5
10
15
TC 11
TC 13
TC 15
TC 17
TC 19

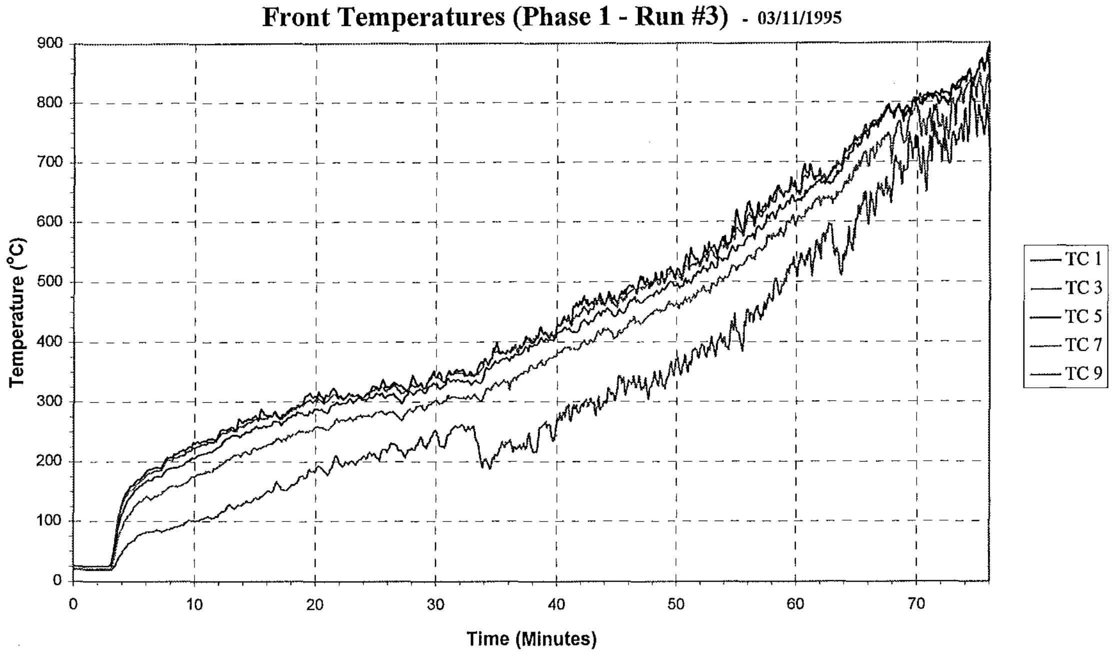

Vent Temperatures (Phase 1 - Run #2) - 02/11/1995
Temperature (°C)
Time (Minutes)
400
300
200
100
0
0
5
10
15
TC 22
TC 25
TC 28
TC 31
TC 34

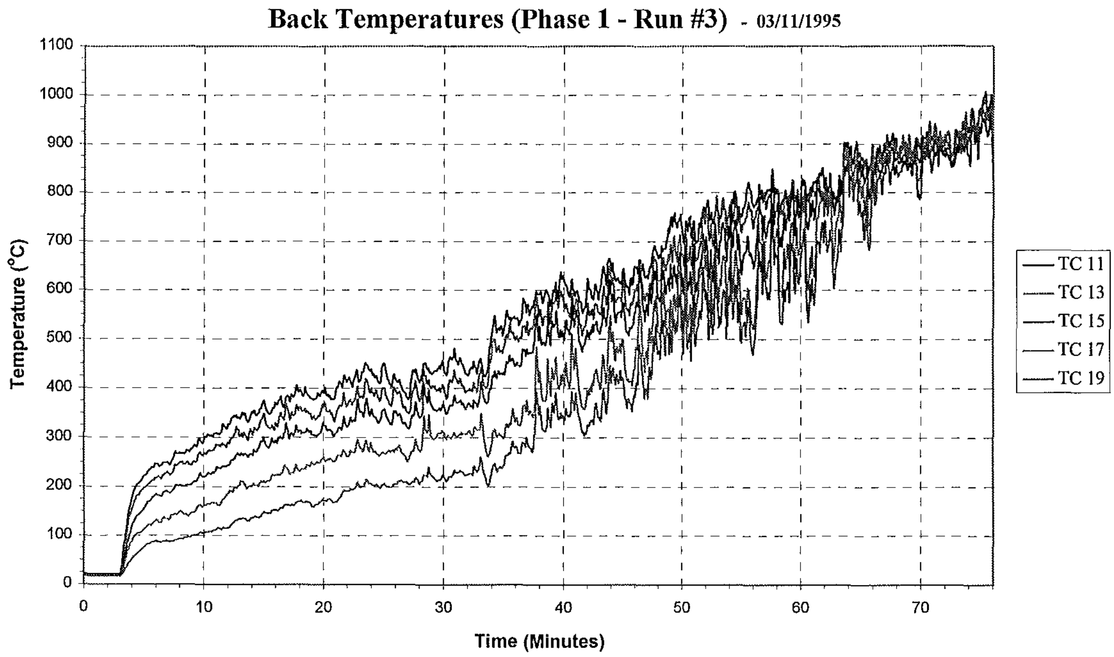
B1. Results from Phase 1 Experiments.

- Test #3

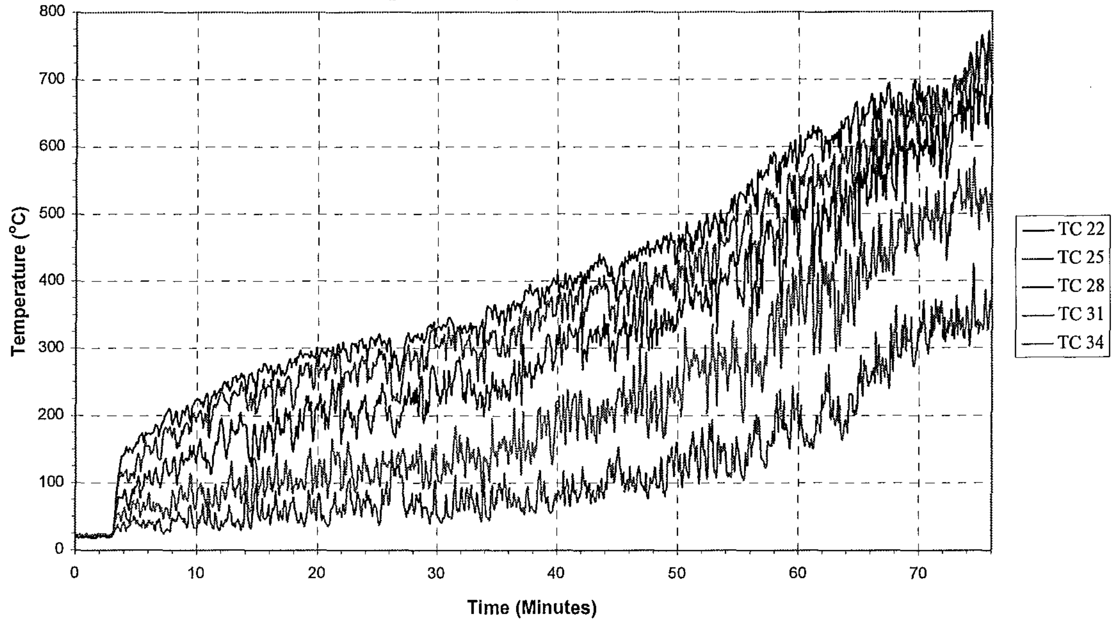




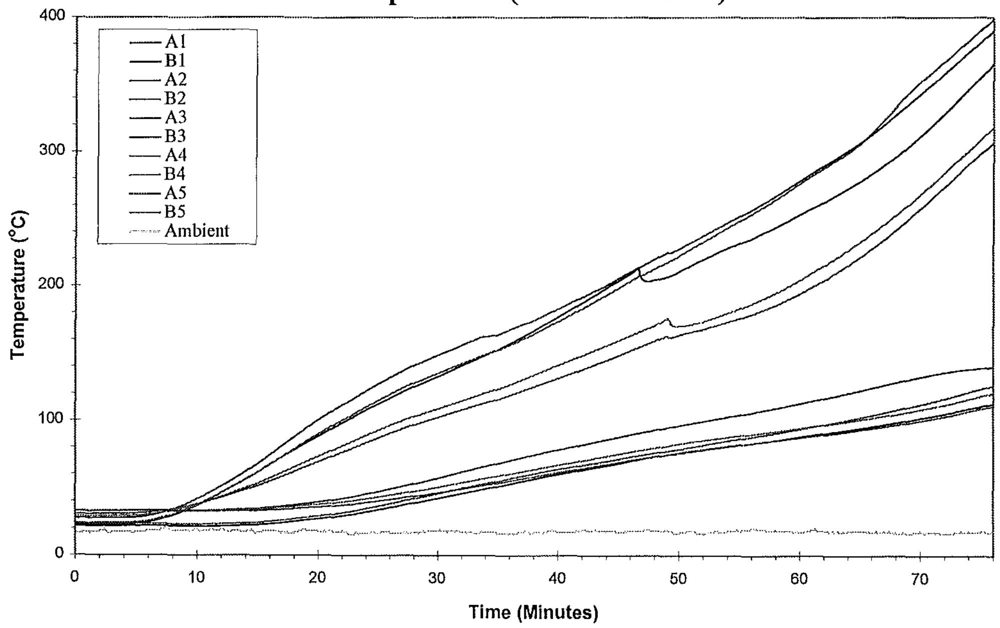

Front Temperatures (Phase 1 - Run #3) - 03/11/1995
900
800
700
600
500
400
300
200
100
0
Temperature (°C)
0
10
20
30
40
50
60
70
Time (Minutes)
TC 1
TC 3
TC 5
TC 7
TC 9


Back Temperatures (Phase 1 - Run #3) - 03/11/1995
1100
1000
900
800
700
600
500
400
300
200
100
0
Temperature (°C)
0
10
20
30
40
50
60
70
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19

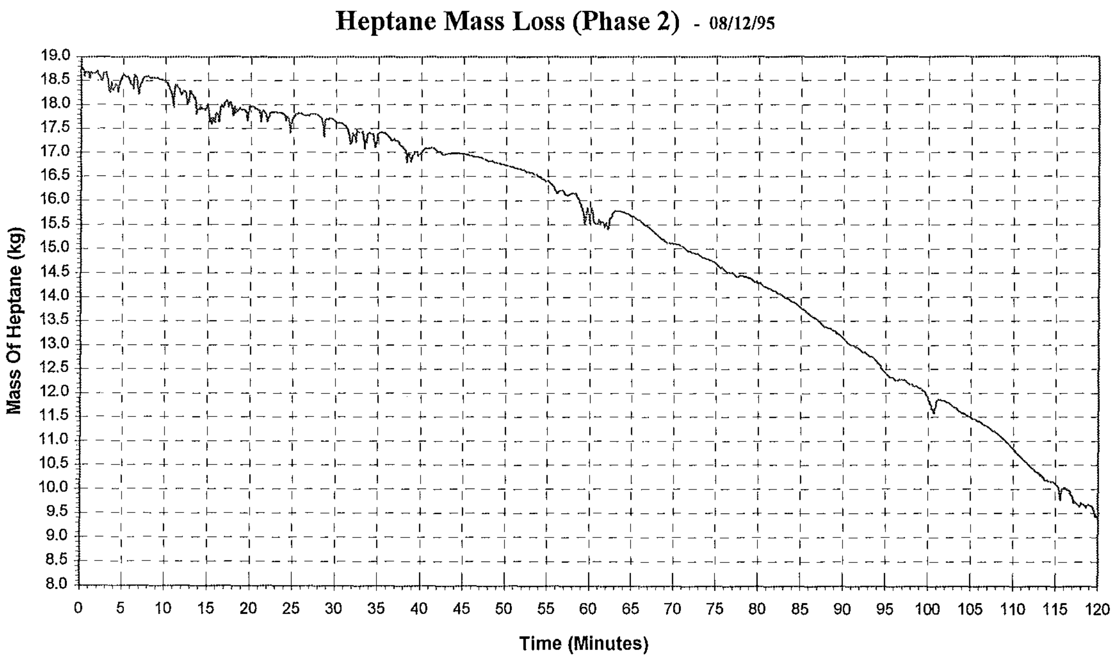
Vent Temperatures (Phase 1 - Run #3) - 03/11/1995

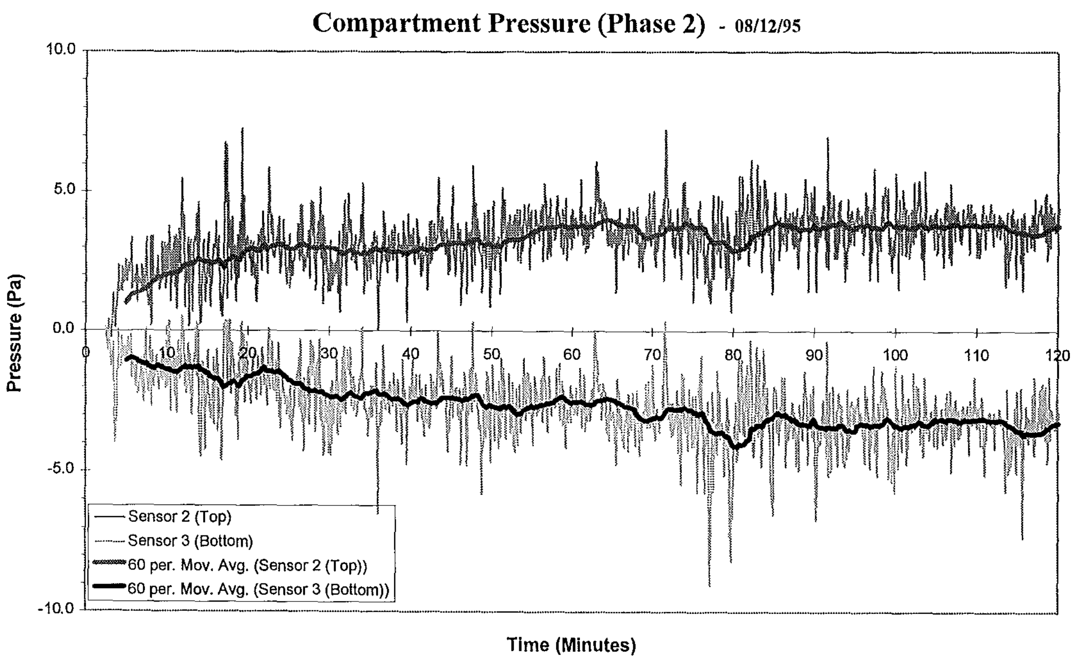


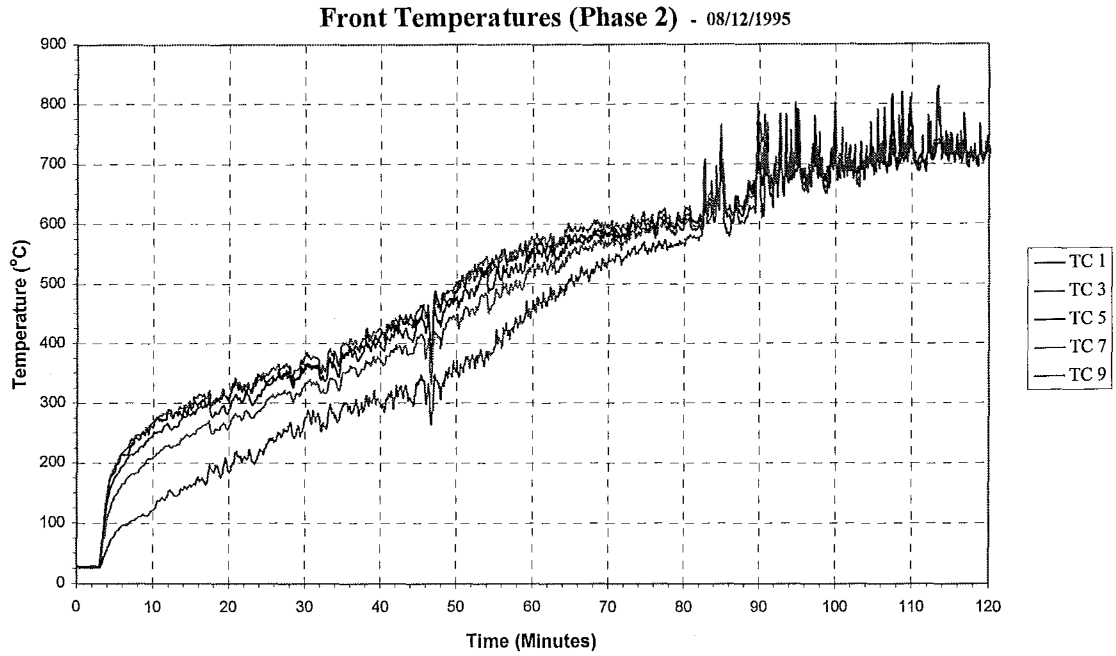
Wall Temperatures (Phase 1 - Run #3) - 03/11/1995

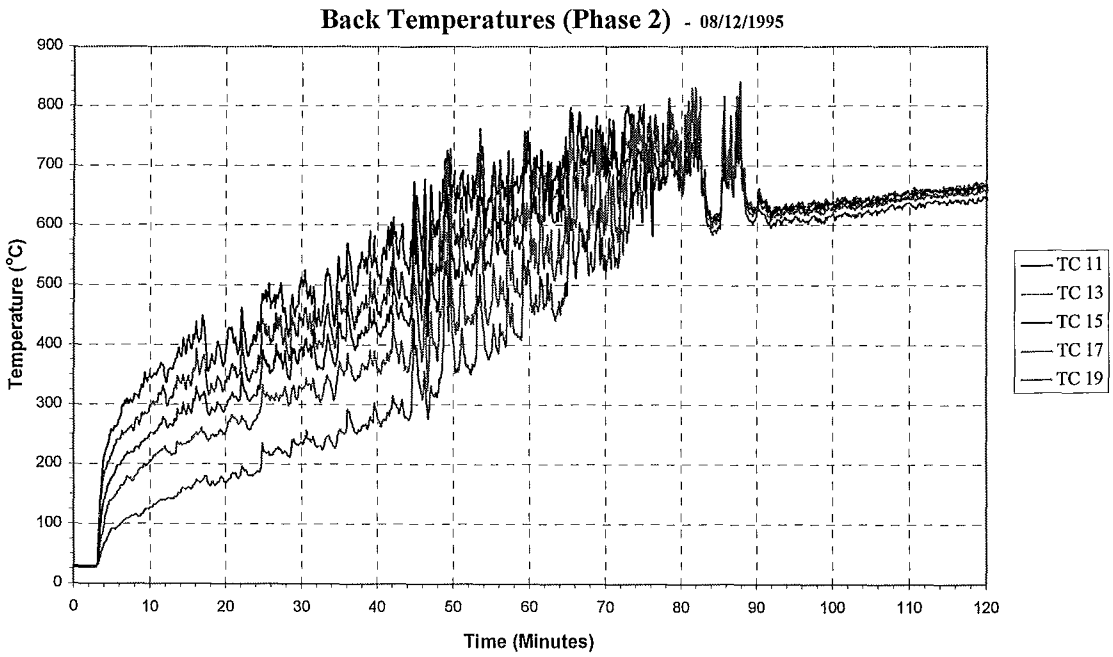


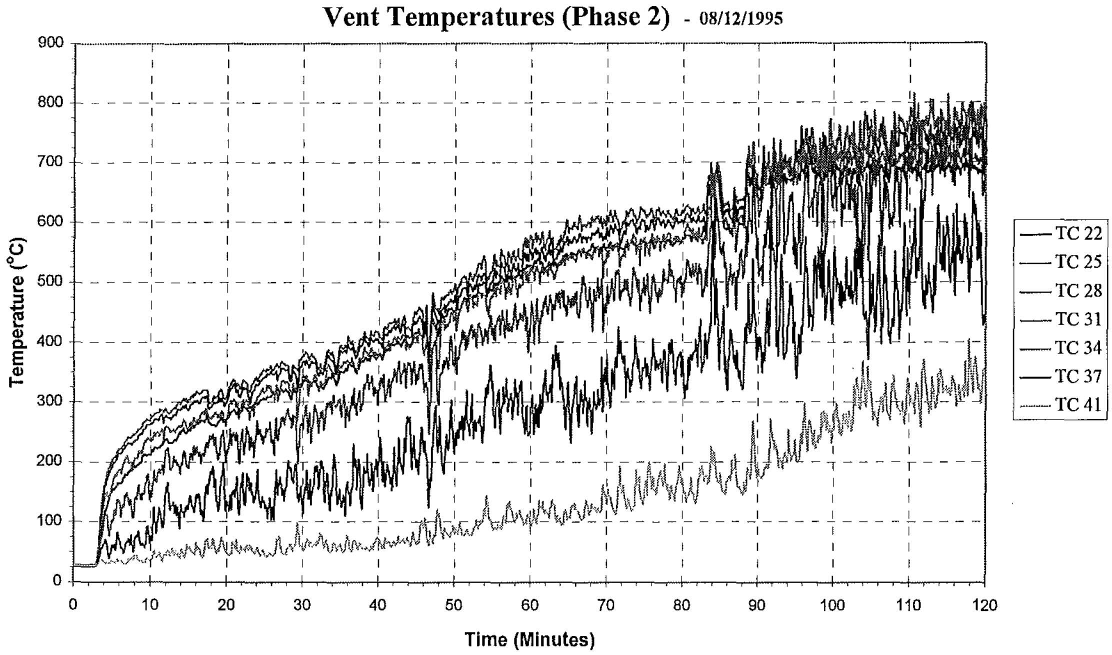
B2. Results from the Phase 2 Experiment.

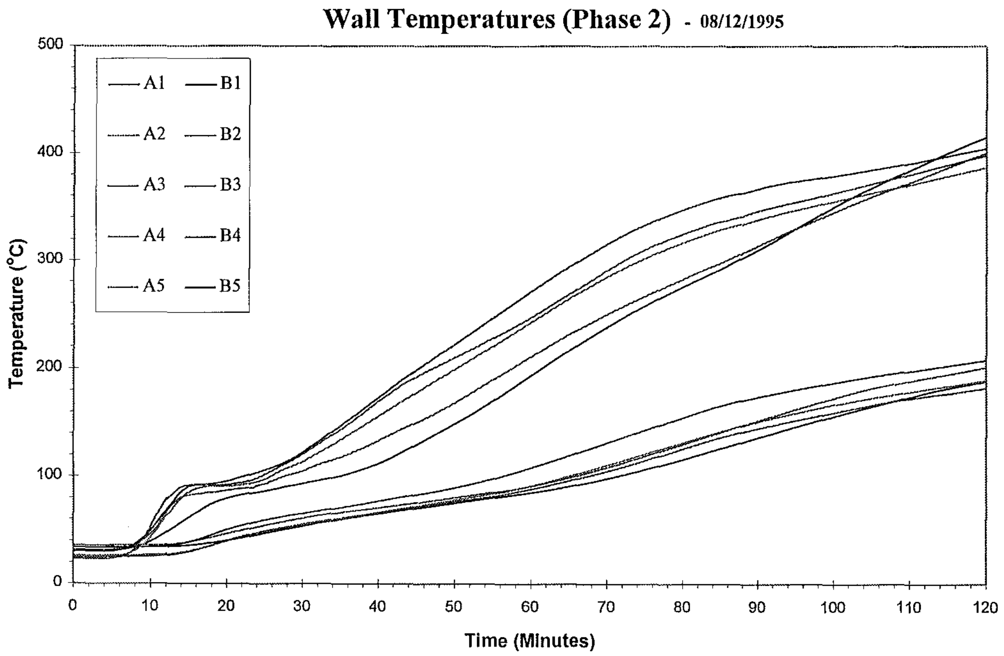


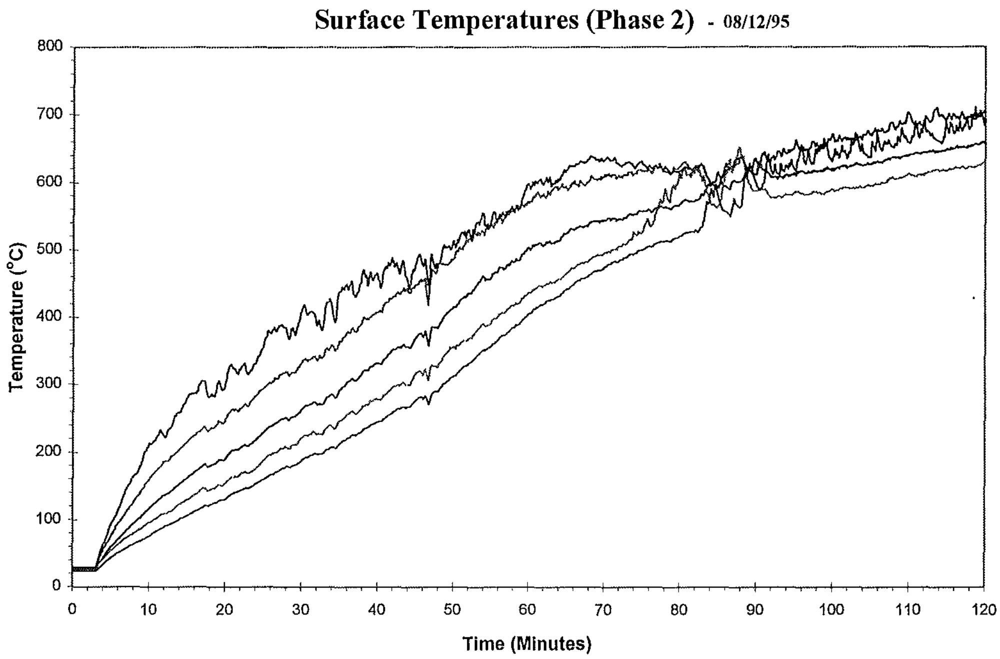



Front Temperatures (Phase 2) - 08/12/1995
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100
110
120
TC 1
TC 3
TC 5
TC 7
TC 9

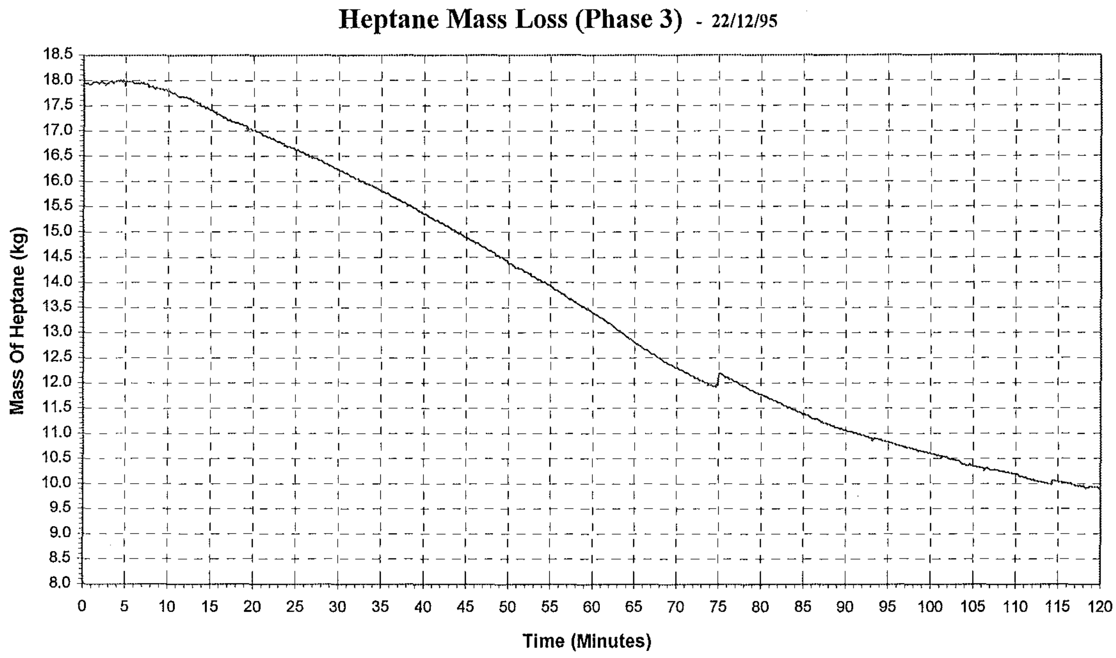

Back Temperatures (Phase 2) - 08/12/1995
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100
110
120
TC 11
TC 13
TC 15
TC 17
TC 19

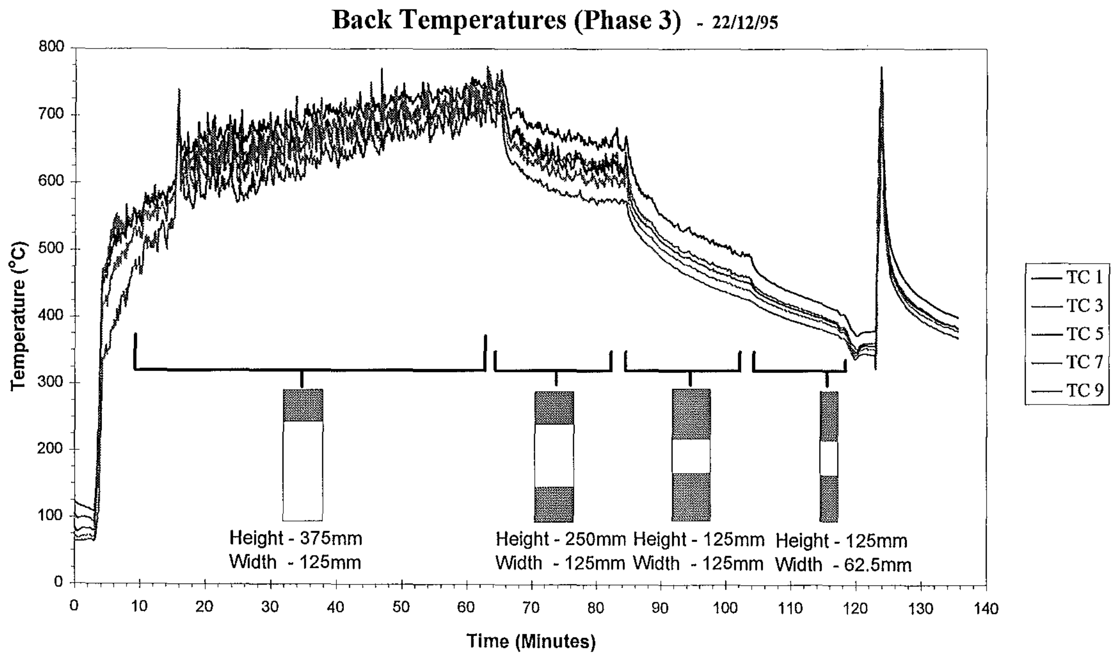

Vent Temperatures (Phase 2) - 08/12/1995
Temperature (°C)
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41

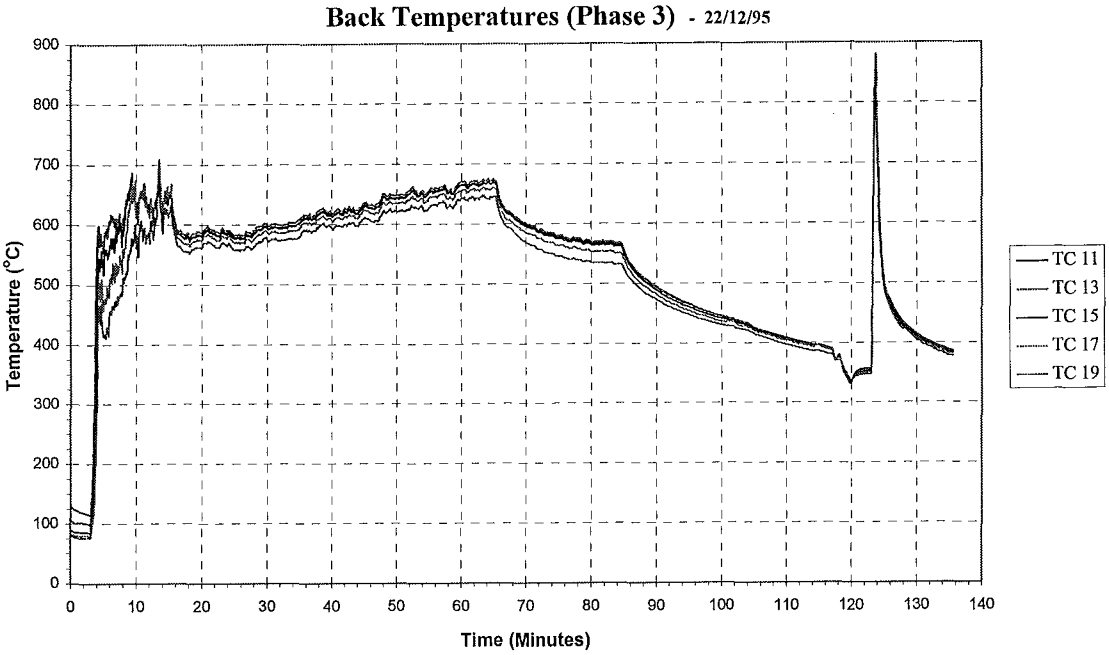

Wall Temperatures (Phase 2) - 08/12/1995
Temperature (°C)
Time (Minutes)
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5

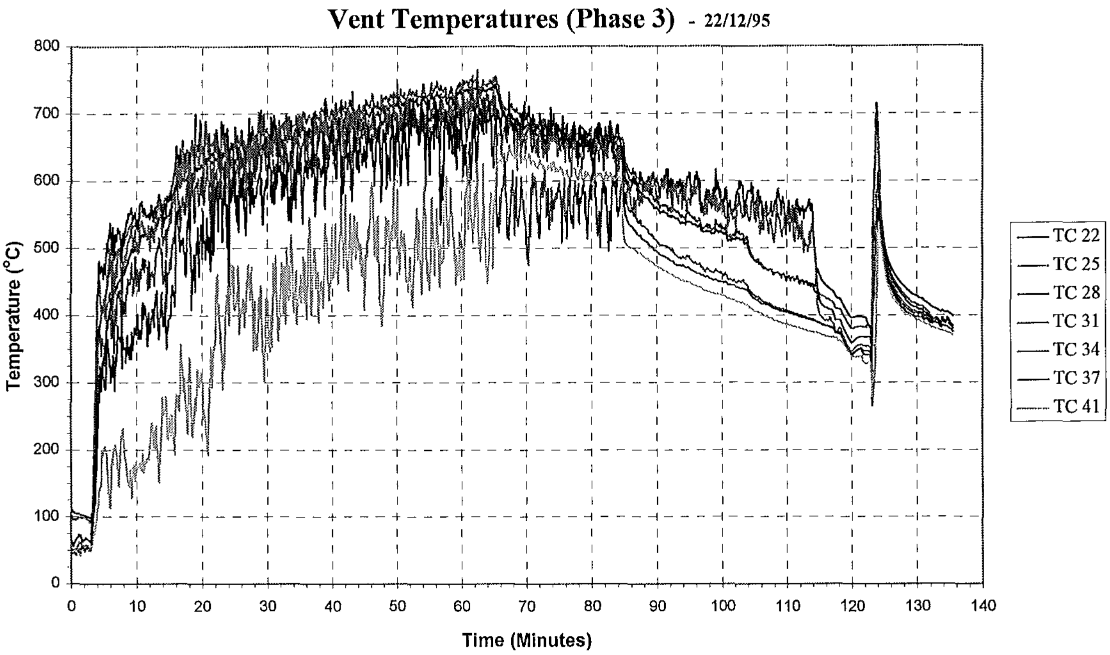

Surface Temperatures (Phase 2) - 08/12/95
Temperature (°C)
0
100
200
300
400
500
600
700
800
Time (Minutes)
0
10
20
30
40
50
60
70
80
90
100
110
120

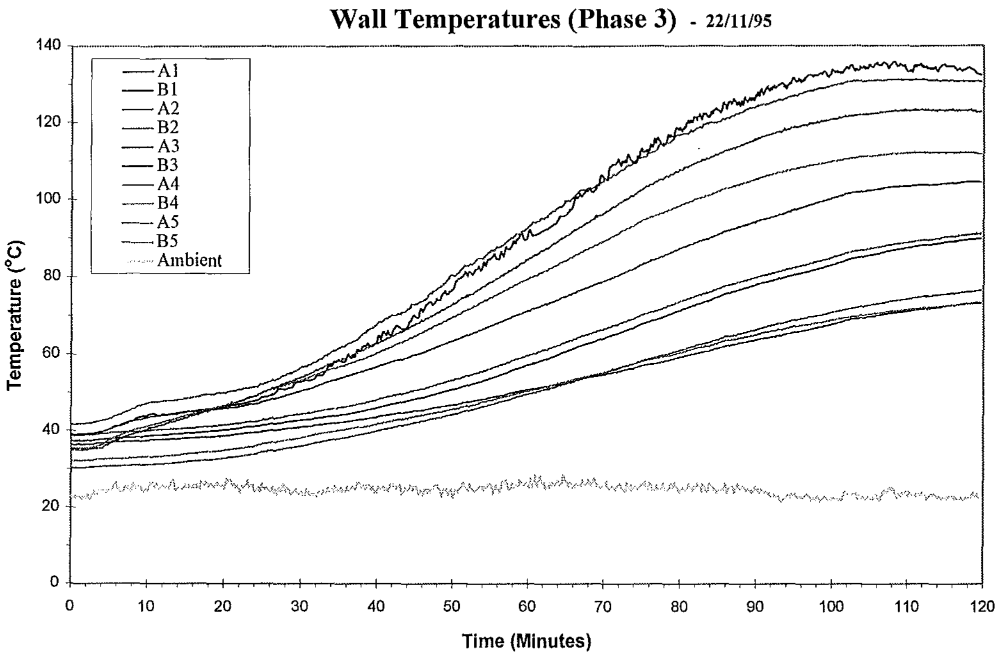
B3. Results from the Phase 3 Experiment.






Back Temperatures (Phase 3) - 22/12/95
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
600
700
800
900
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
TC 11
TC 13
TC 15
TC 17
TC 19


Vent Temperatures (Phase 3) - 22/12/95
Temperature (°C)
Time (Minutes)
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41


Wall Temperatures (Phase 3) - 22/11/95
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
Time (Minutes)
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80
90
100
110
120

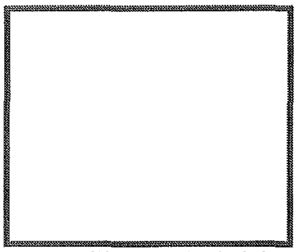
Appendix C. Results from Furnace Tests on Promatect® H

C1. Single Layer Tests.

C2. Double Layer Tests.

C1. Single Layer Tests.

Initial Dimensions:



NS Side
199.62 mm

EW Side 199.84 mm

Coefficient Of Expansion (20 - 600°)
-6.40E-06 m/mK

Table 1. Differential temperature results.

Temp. °C	Time	Readings (mm) 1	2	3	Ave.	Theoretical expansion (mm)	Actual expansion (mm)	Change from previous reading
500	**1 Hour**							
	NS Side	199.60	199.60	199.60	199.60	-0.988	-0.02	-0.02
	EW Side	199.82	199.84	199.82	199.83	-0.989	-0.01	-0.01
	2 Hours							
	NS Side	199.50	199.46	199.50	199.49	-0.988	-0.13	-0.11
	EW Side	199.82	199.82	199.80	199.81	-0.989	-0.03	-0.01
750	**1 Hour**							
	NS Side	199.42	199.40	199.34	199.39	-1.307	-0.23	-0.10
	EW Side	199.66	199.66	199.62	199.65	-1.308	-0.19	-0.17
	2 Hours							
	NS Side	199.12	199.10	199.10	199.11	-1.307	-0.51	-0.28
	EW Side	199.54	199.52	199.52	199.53	-1.308	-0.31	-0.12
1000	**1 Hour**							
	NS Side	199.00	198.86	198.86	198.91	-1.626	-0.71	-0.20
	EW Side	199.42	199.40	199.38	199.40	-1.628	-0.44	-0.13
	2 Hours							
	NS Side	198.84	198.80	198.80	198.81	-1.626	-0.81	-0.09
	EW Side	199.34	199.34	199.32	199.33	-1.628	-0.51	-0.07

Throughout the experiment it was difficult to measure the dimensions of the board to a high accuracy, as vernier callipers were used within asbestos gloves. The boards fibrous cohesion also deteriorated with the increasing exposure to heat. It was also noticeable that the board cooled quickly, along with a speedy contraction due to this cooling.

Table 2. Overnight exposure results.

Temp °C	Time	Readings (mm) 1	2	3	Ave.	Expected expansion (mm)	Actual expansion (mm)	Change from previous reading
Overnight	**13 Hours**							
1000	NS Side	198.60	198.54	198.46	198.53	-1.626	-1.09	-1.09
	EW Side	199.70	199.66	199.62	199.66	-1.628	-0.18	-0.18

Table 3. Cooling down results.

NS Side reading (mm)	Change from previous reading.	EW Side reading (mm)	Change from previous reading.
199.66		198.53	
199.02	-0.64	198.00	-0.53
198.80	-0.22	197.96	-0.04
198.74	-0.06	197.79	-0.17
198.74	0.00	197.82	0.03
198.72	-0.02	197.74	-0.08
198.74	0.02	197.76	0.02
198.74	0.00	197.78	0.02
198.74	0.00	197.74	-0.04
Total Change	-0.92		-0.79

Table 4. Repeated heating results.

NS Side reading (mm)	Change from previous reading.	EW Side reading (mm)	Change from previous reading.
197.90		198.74	
198.36	0.46	199.52	0.78
198.04	-0.32	198.98	-0.54
197.88	-0.16	198.79	-0.19
197.8	-0.08	198.74	-0.05
197.76	-0.04	198.76	0.02
Total Change	-0.14	198.76	0.02

C2. Double Layer Tests.

Table 5. Double layer heating results.

Top Panel

Outside Face				Inside Face			
NS Side reading (mm)	**Change from previous**	**EW Side reading (mm)**	**Change from previous**	**NS Side reading (mm)**	**Change from previous**	**EW Side reading (mm)**	**Change from previous**
198.58		198.42		198.50		198.44	
197.74	-0.84	198.12	-0.30	197.46	-1.04	198.02	-0.42
197.32	-0.42	197.64	-0.48	197.14	-0.32	197.66	-0.36
197.20	-0.12	196.52	-1.12	196.78	-0.36	197.44	-0.22
197.22	0.02	196.50	-0.02	196.84	0.06	197.46	0.02

Bottom Panel

Outside Face				Inside Face			
NS Side reading (mm)	**Change from previous**	**EW Side reading (mm)**	**Change from previous**	**NS Side reading (mm)**	**Change from previous**	**EW Side reading (mm)**	**Change from previous**
196.58		199.72		196.80		199.74	
195.86	-0.72	199.22	-0.50	195.78	-1.02	199.22	-0.52
195.66	-0.20	198.72	-0.50	195.54	-0.24	199.12	-0.10
195.58	-0.08	198.70	-0.02	195.50	-0.04	198.98	-0.14
195.44	-0.14	198.78	0.08	195.56	0.06	198.92	-0.06

No distinguishable bending was noticed

- Double layer test with connection.

The Promatect H was exposed to 1000°C for 2 hours.
The screw/washer and fixing withstood 1000°C well in the first hour. After the second hour it was found that the screw came apart from the fixing (which had melted). The washer had also became welded to the screw head.

- Double layer test with capped connection and Multiflex sealer.

The Promatect H was exposed to 1000°C for 2 hours.
At the end of this period the Multiflex had become hardened and brittle and the screw came apart from the fixing (which had melted to a lesser degree than before).

Appendix D. Experimental Results

- TEST # 1: - Monday, January 8, 1996

Ventilation	Dimension	Nomenclature
Height:	500 mm	Full
Width:	125 mm	$^1/_4$

- TEST # 2: - Tuesday, January 9, 1996

Ventilation	Dimension	Nomenclature
Height:	500 mm	Full
Width:	62.5 mm	$^1/_8$

- TEST # 3: - Tuesday, January 9, 1996

Ventilation	Dimension	Nomenclature
Height:	500 mm	Full
Width:	31.25 mm	$^1/_{16}$

- TEST # 4: - Thursday, January 11, 1996

Ventilation	Dimension	Nomenclature
Height:	375 mm	Top down $^1/_4$
Width:	125 mm	$^1/_4$

- TEST # 5: - Monday, January 15, 1996

Ventilation	Dimension	Nomenclature
Height:	375 mm	Top down $^1/_4$
Width:	62.5 mm	$^1/_8$

- TEST # 6: - Tuesday, January 16, 1996

Ventilation	Dimension	Nomenclature
Height:	375 mm	Top down $^1/_4$
Width:	31.25 mm	$^1/_{16}$

- TEST # 7: - Wednesday, January 17, 1996

Ventilation	Dimension	Nomenclature
Height:	250 mm	Top down $^1/_2$
Width:	125 mm	$^1/_4$

- TEST # 8: - Thursday, January 18, 1996

Ventilation	Dimension	Nomenclature
Height:	250 mm	Top down $^1/_2$
Width:	62.5 mm	$^1/_8$

- TEST # 9 & 10: - Friday, January 19, 1996

Ventilation	Dimension	Nomenclature
Height:	250 mm	Top down $^1/_2$
Width:	31.25 mm	$^1/_{16}$

- TEST # 11: - Friday, January 19, 1996

Ventilation	Dimension	Nomenclature
Height:	250 mm	Bottom up $^1/_2$
Width:	125 mm	$^1/_4$

- TEST # 12: - Monday, January 22, 1996

Ventilation	Dimension	Nomenclature
Height:	500 mm	Full
Width:	31.25 mm	$^1/_{16}$

- TEST # 13: - Tuesday, January 23, 1996

Ventilation	Dimension	Nomenclature
Height:	375 mm	Top Down $^1/_4$
Width:	31.25 mm	$^1/_{16}$

- TEST # 14: - Thursday, January 25, 1996

Ventilation	Dimension	Nomenclature
Height:	500 mm	Full
Width:	125 mm	$^1/_4$

- TEST # 15: - Friday, February 2, 1996

Free Burn

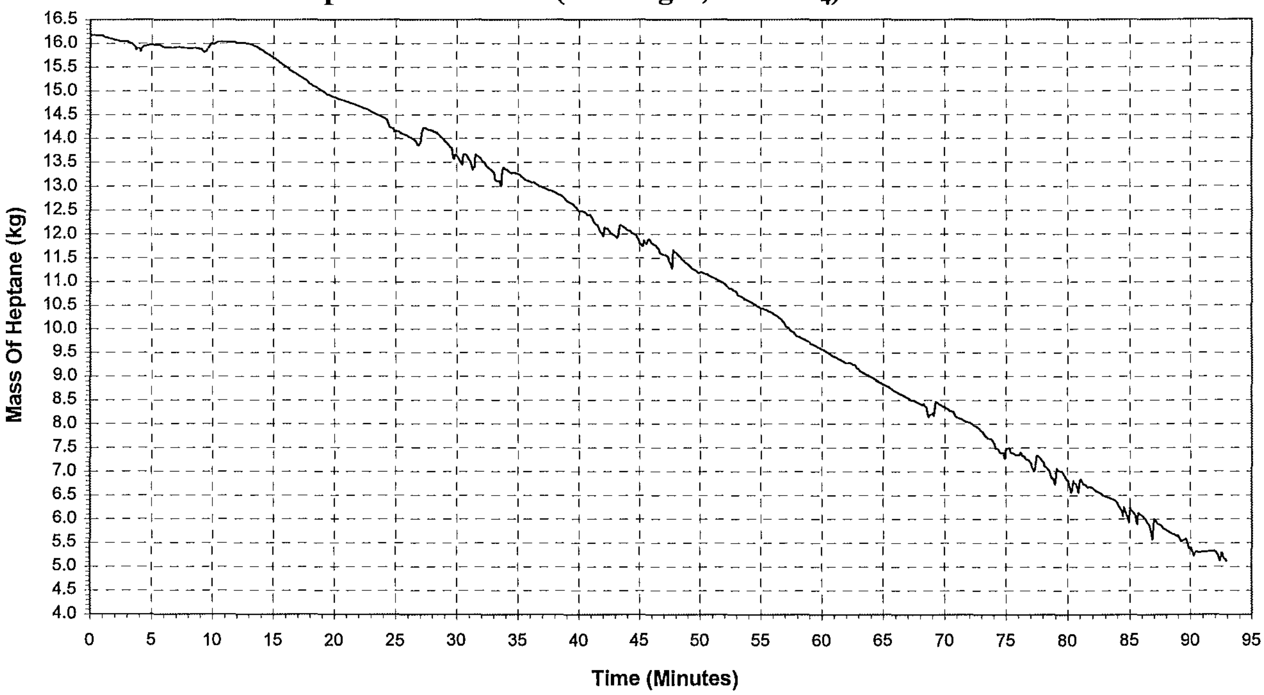
TEST #1.

Ventilation Opening: Height - Full
Width - $^1/_4$

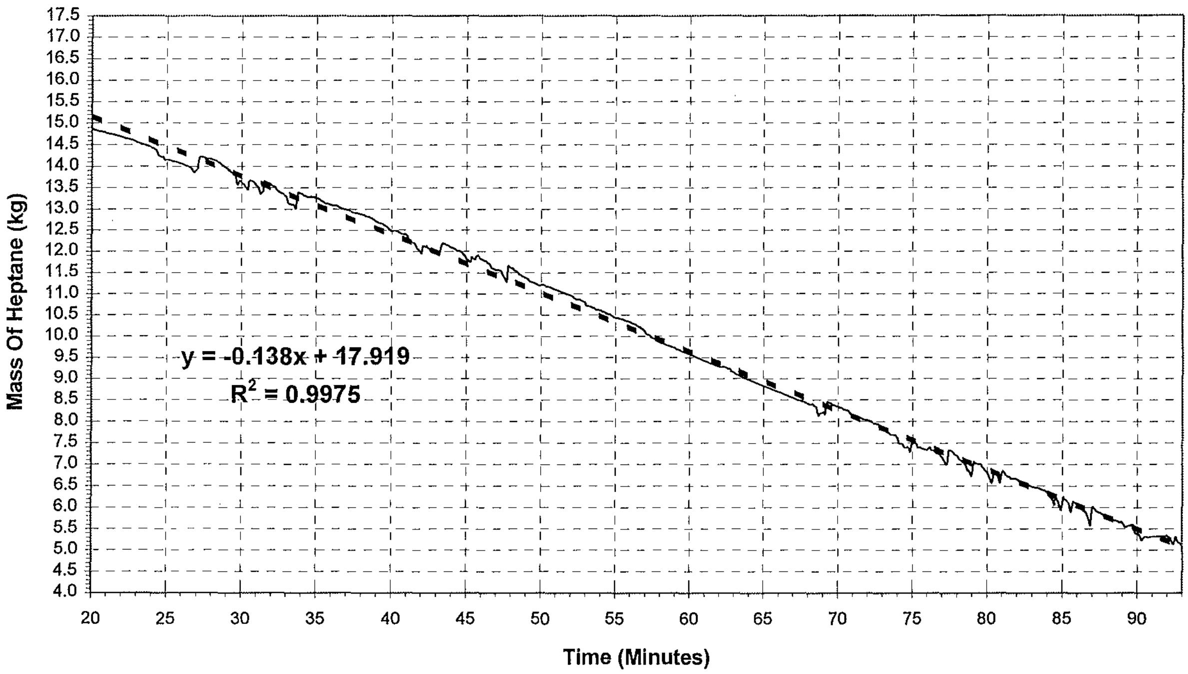
Weather Conditions: Average wind speed = 1.2 m/s
Maximum wind speed = 2.1 m/s

Comments: A constant head was not kept in the pan at all times. The Pan level dropped @ 10 minutes into the fire for approx. 2 minutes before being noticed.

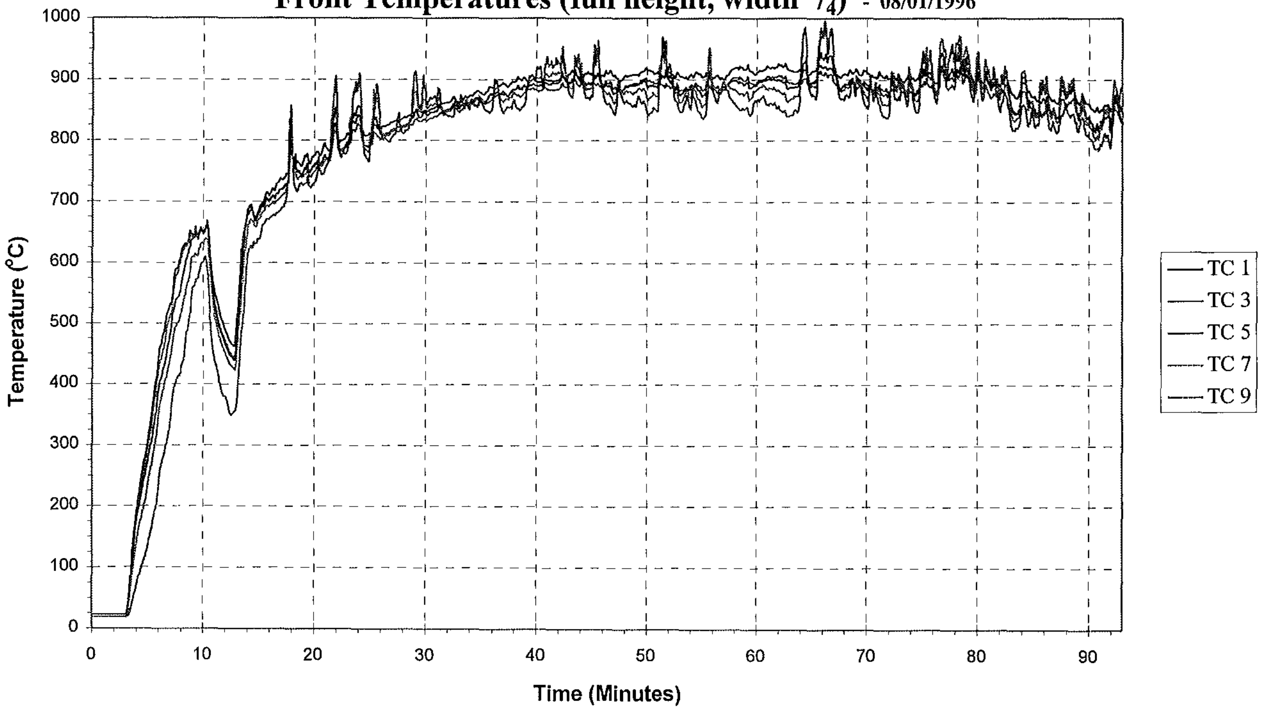
Heptane Mass Loss (full height, width $^1/_4$) - 08/01/1996



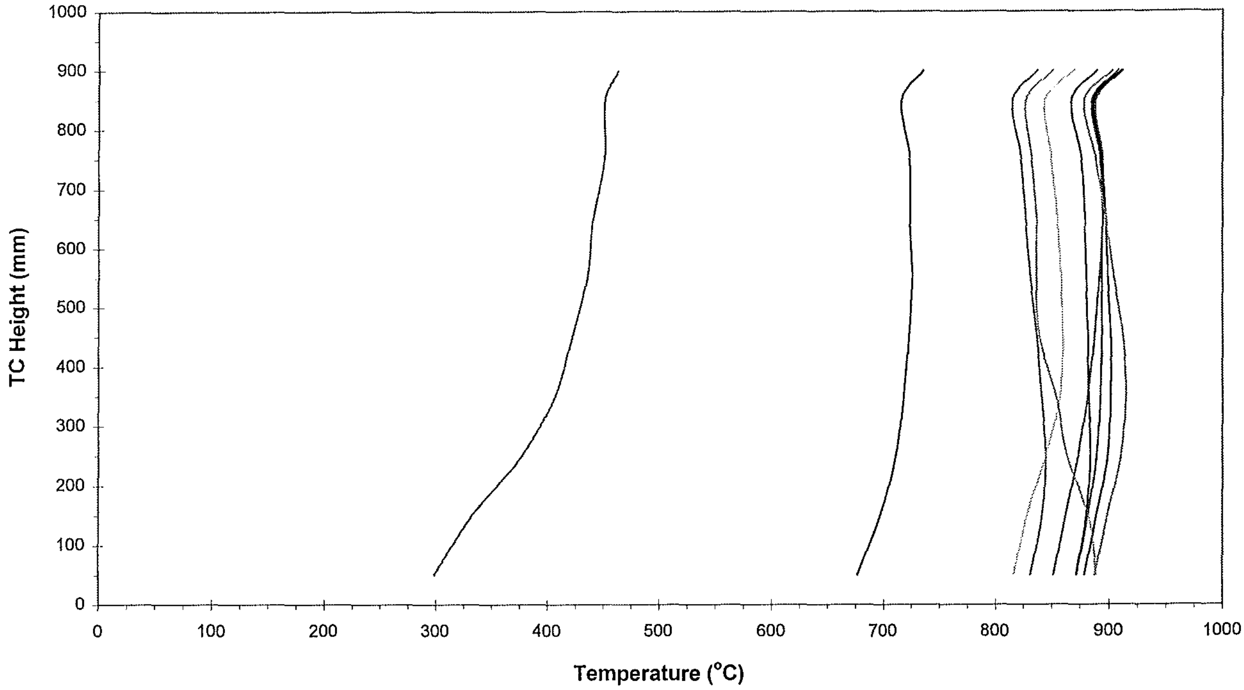
Mass Loss Rate (full height, width $^1/_4$) - 08/01/1996



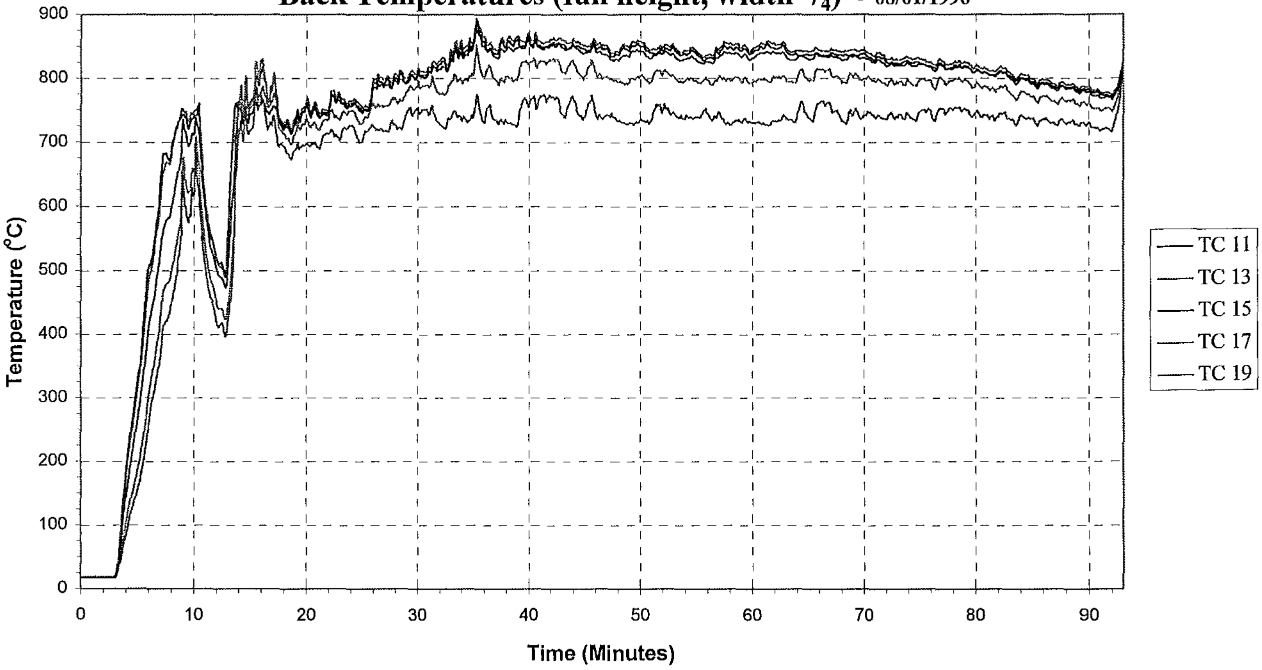
Front Temperatures (full height, width $^1/_4$) - 08/01/1996

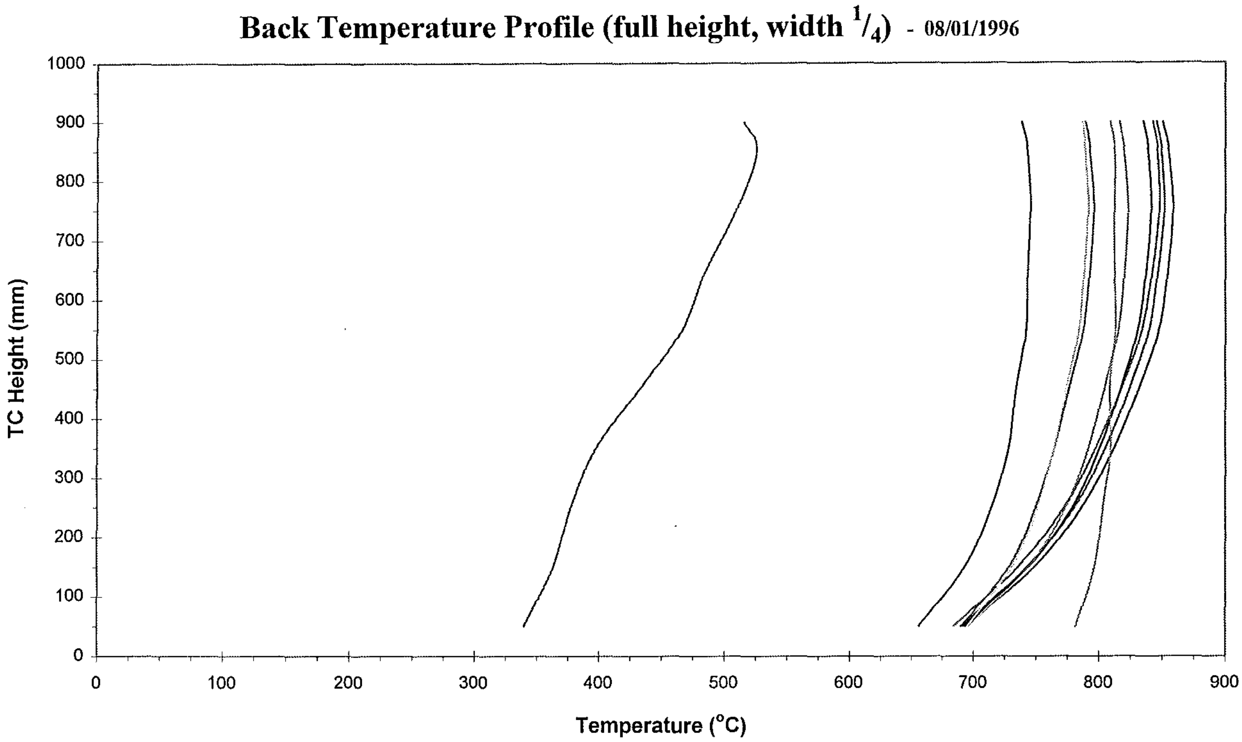


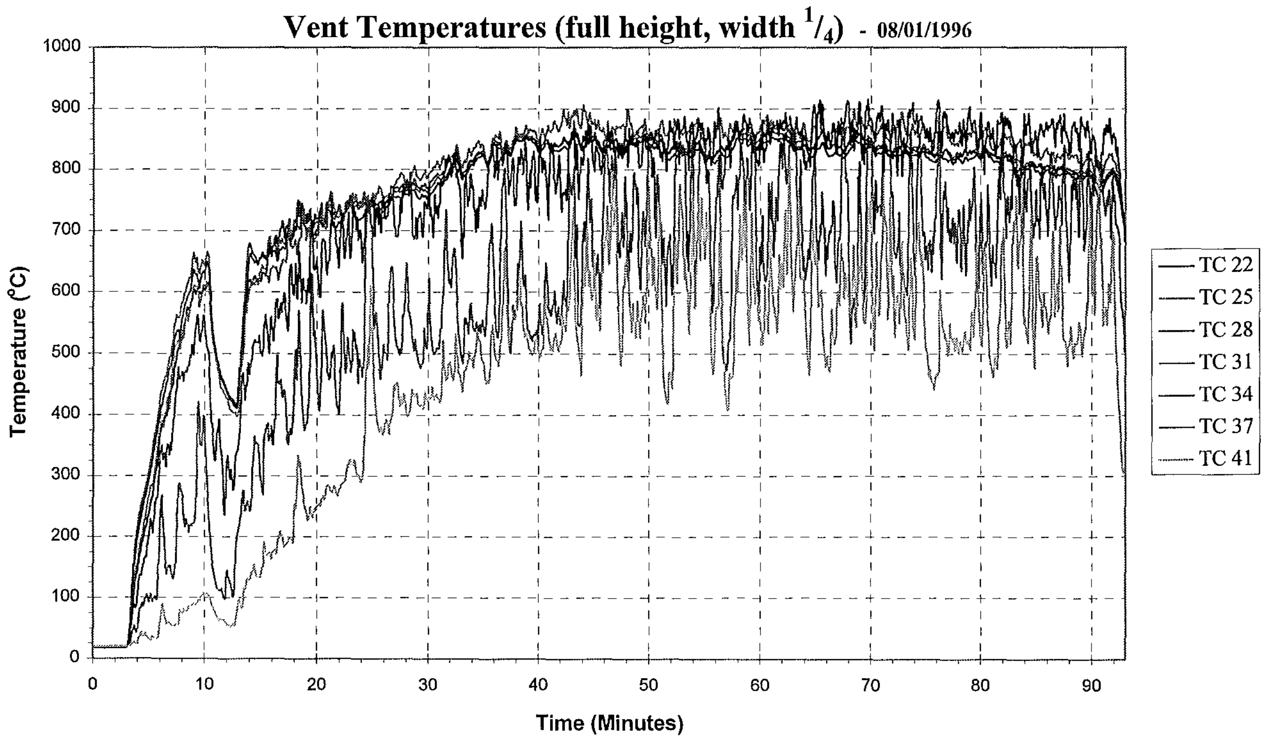
Front Temperature Profile (full height, width 1/4) - 08/01/1996



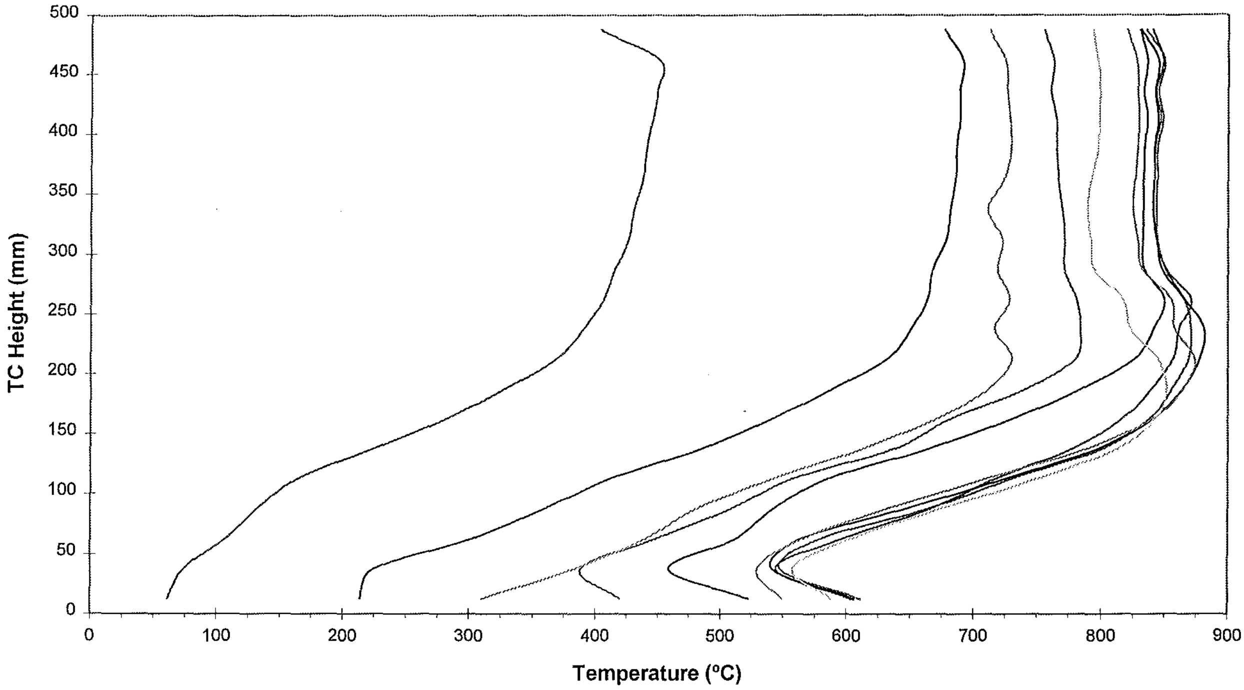
Back Temperatures (full height, width 1/4) - 08/01/1996



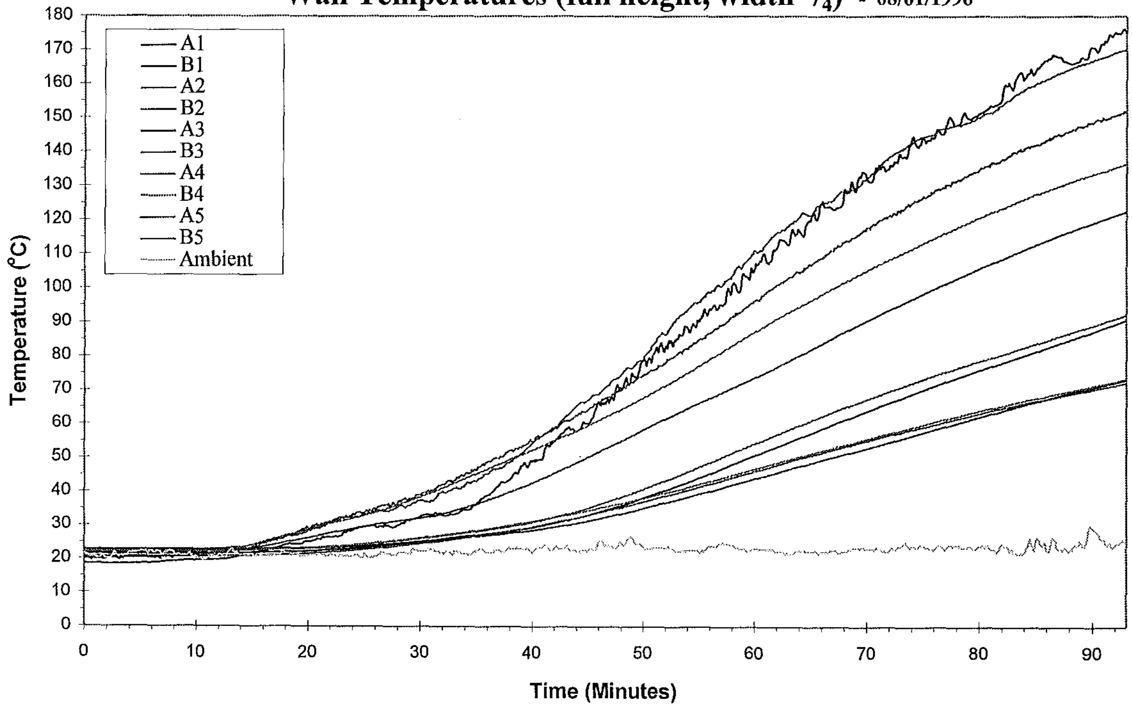

Back Temperature Profile (full height, width 1/4) - 08/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000


Vent Temperatures (full height, width 1/4) - 08/01/1996
Temperature (°C)
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41

Vent Temperature Profile (full height, width $^1/_4$) - 08/01/1996



Wall Temperatures (full height, width $^1/_4$) - 08/01/1996



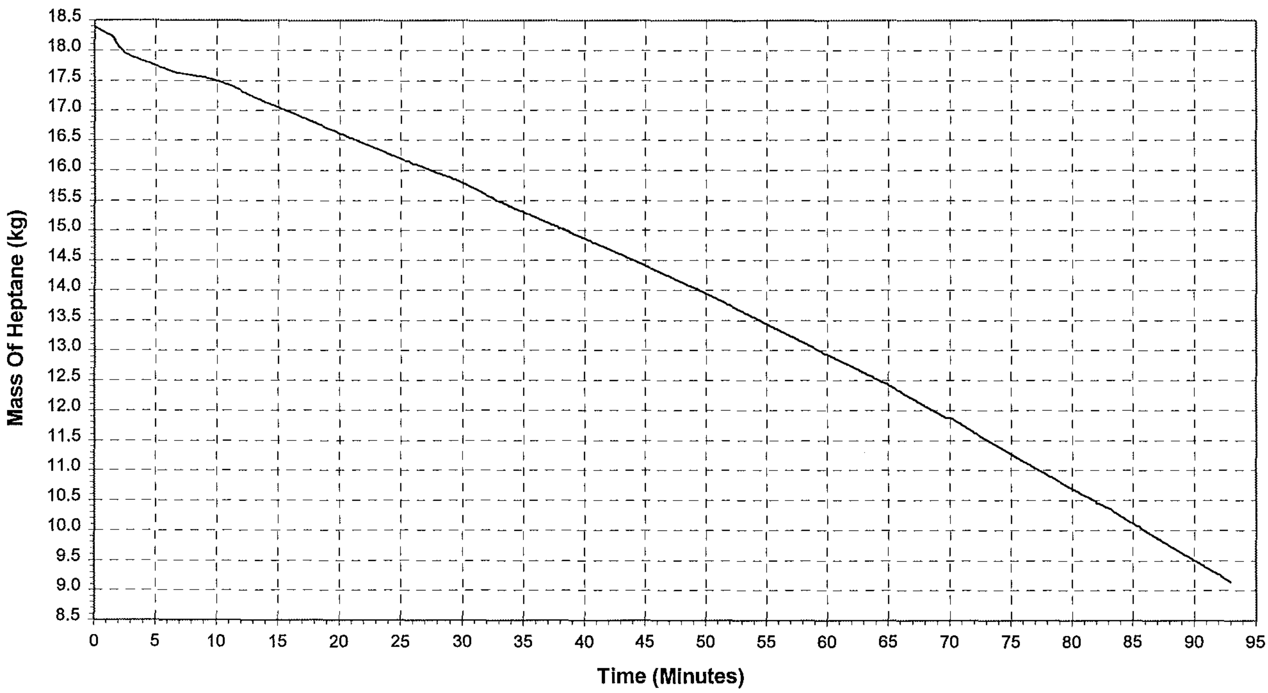
TEST #2.

Ventilation Opening: Height - Full
Width - $^1/_8$

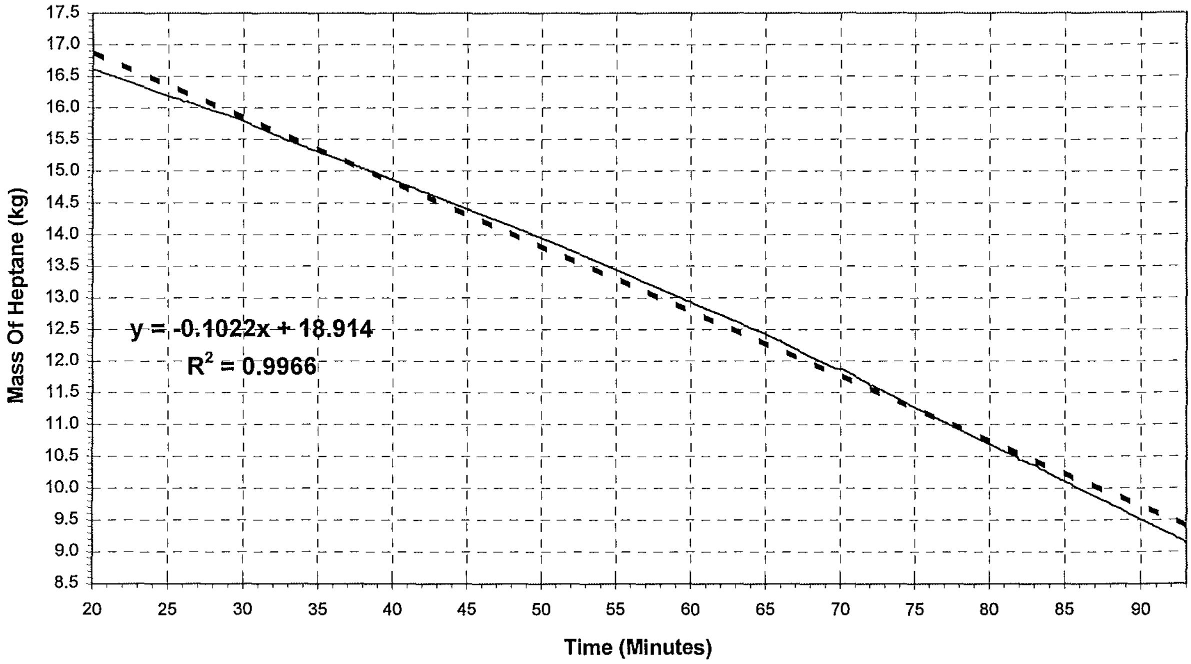
Weather Conditions: Average wind speed = 1.3 m/s
Maximum wind speed = 3.7 m/s

Comments:

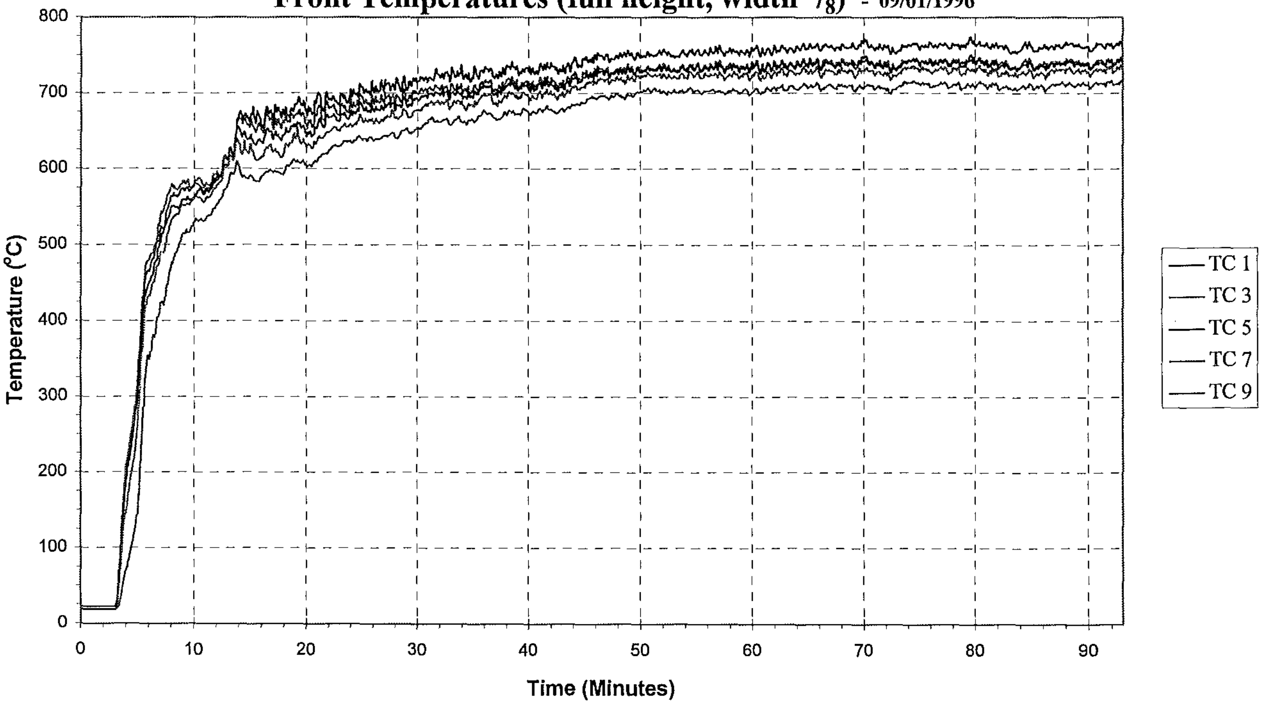
Heptane Mass Loss (full height, width $^1/_8$) - 09/01/1996

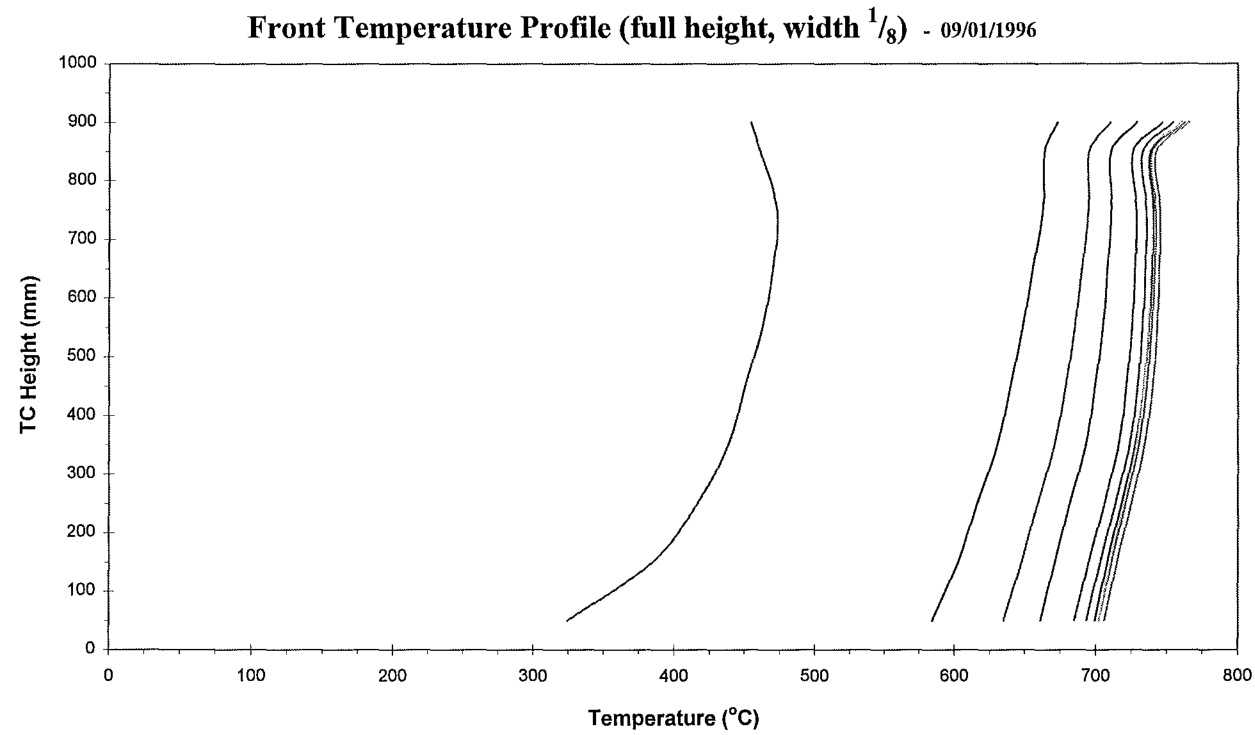


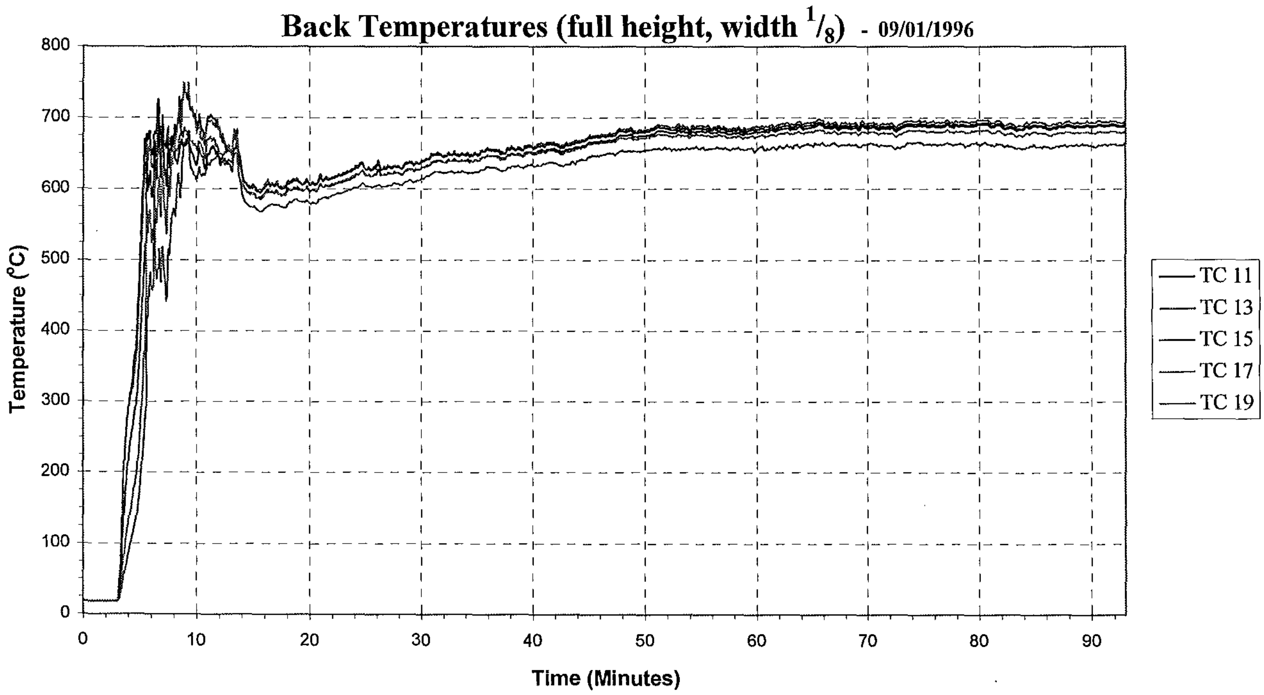
Mass Loss Rate (full height, width 1/8) - 09/01/1996

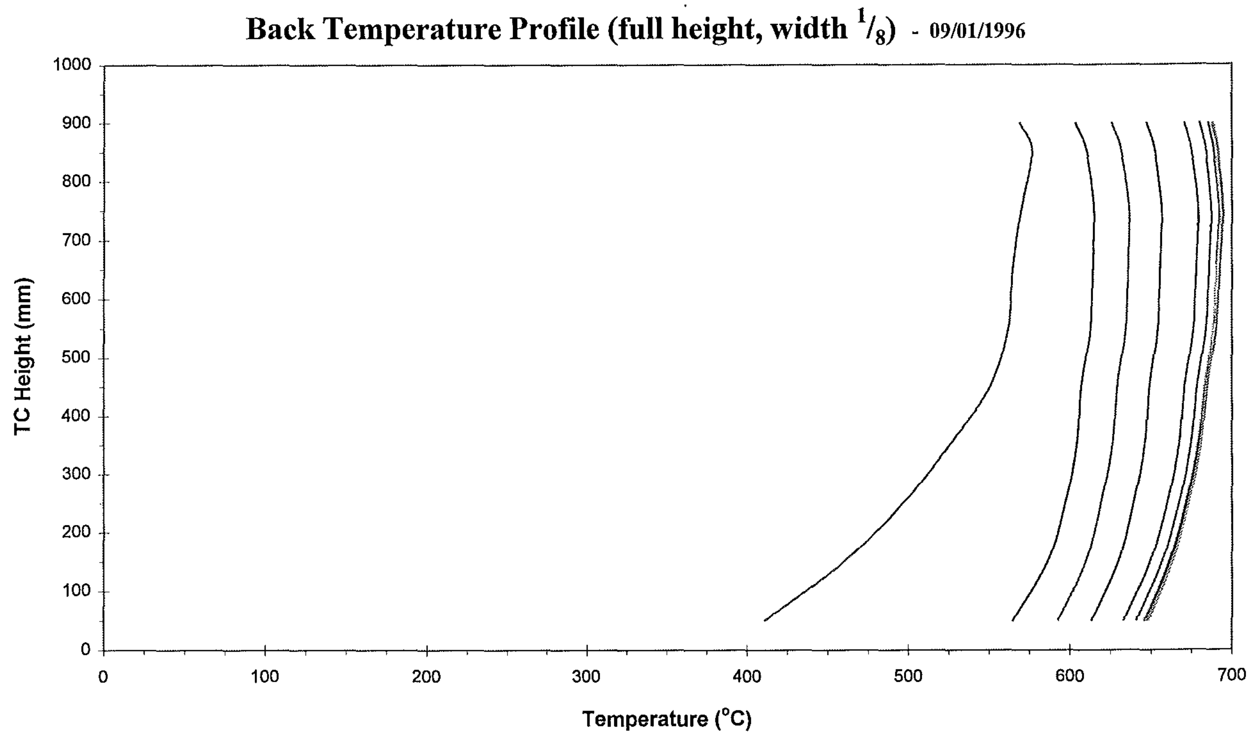


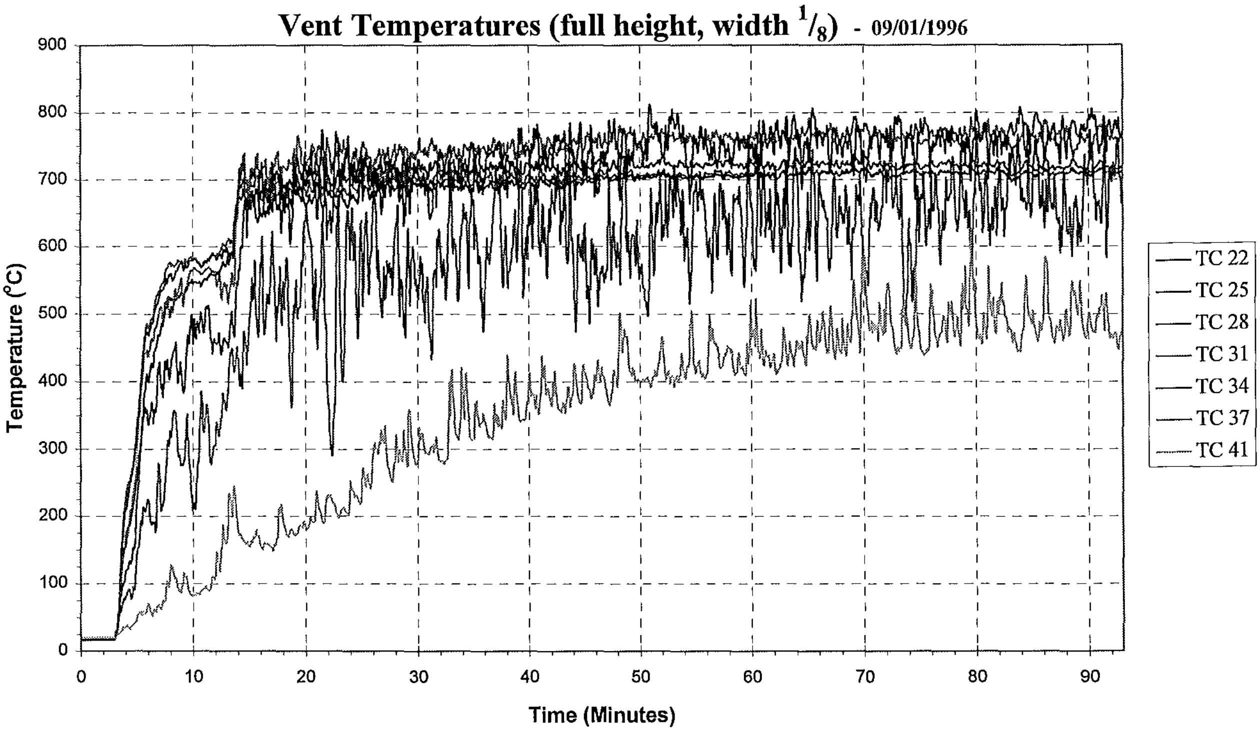
Front Temperatures (full height, width 1/8) - 09/01/1996

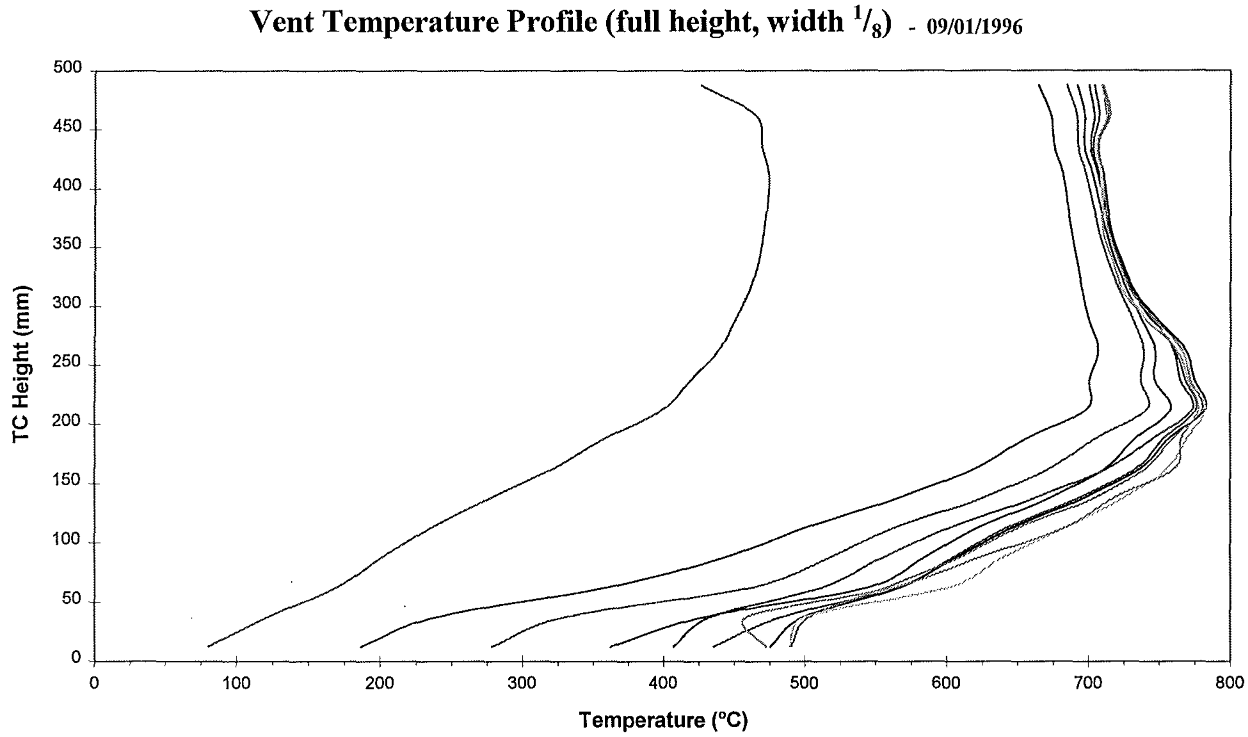


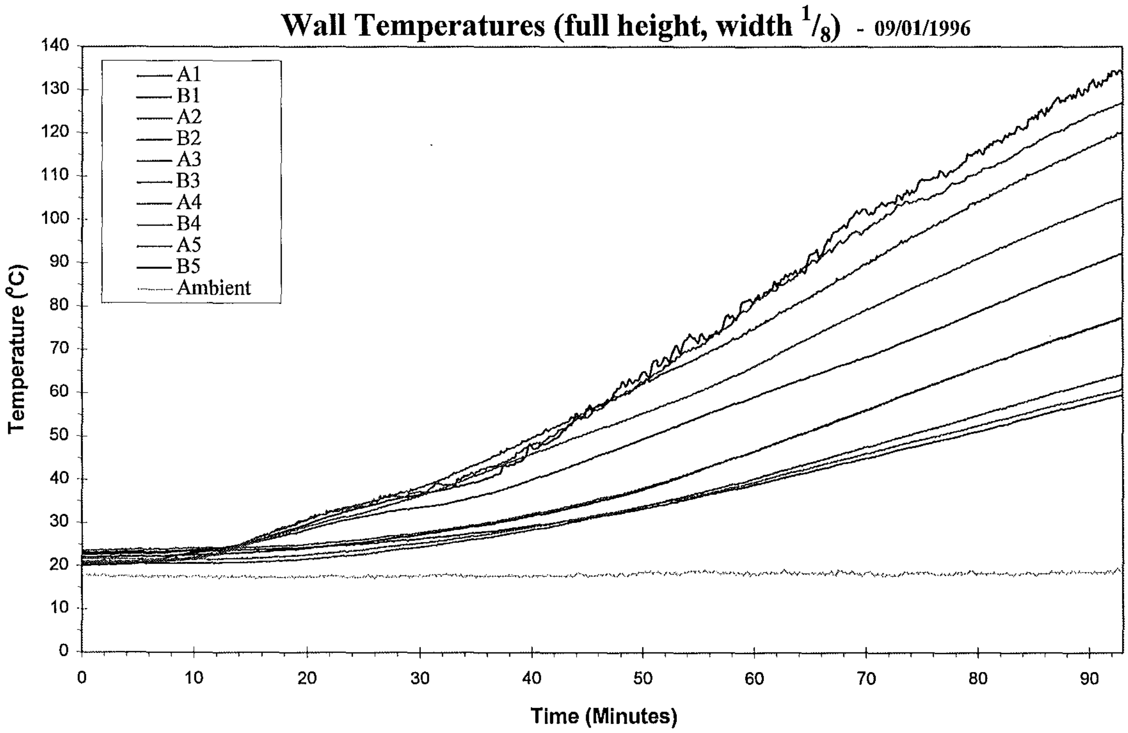

Front Temperature Profile (full height, width 1/8) - 09/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
Temperature (°C)


Back Temperatures (full height, width 1/8) - 09/01/1996
Temperature (°C)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19


Back Temperature Profile (full height, width 1/8) - 09/01/1996
TC Height (mm)
0
100
200
300
400
500
600
700
800
900
1000
Temperature (°C)
0
100
200
300
400
500
600
700


Vent Temperatures (full height, width 1/8) - 09/01/1996
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
Time (Minutes)
0
10
20
30
40
50
60
70
80
90
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41

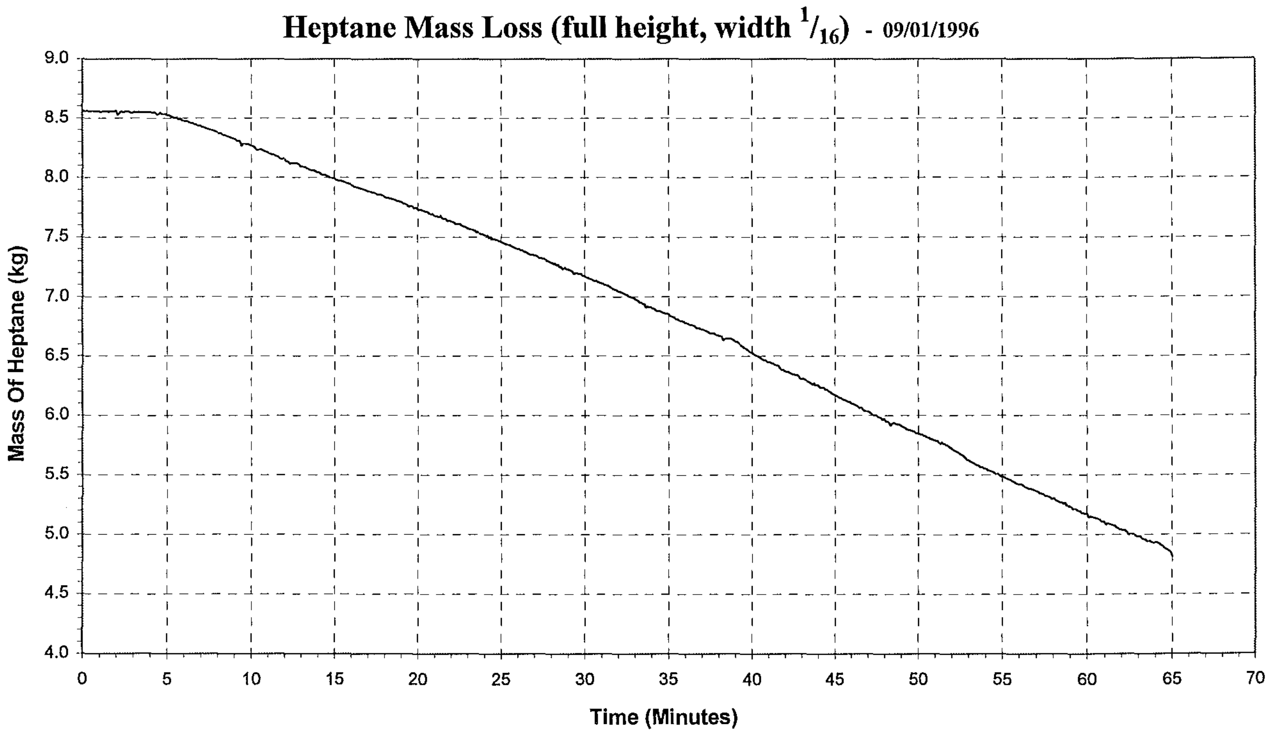

Vent Temperature Profile (full height, width 1/8) - 09/01/1996
TC Height (mm)
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800


Wall Temperatures (full height, width 1/8) - 09/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
Time (Minutes)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
10
20
30
40
50
60
70
80
90

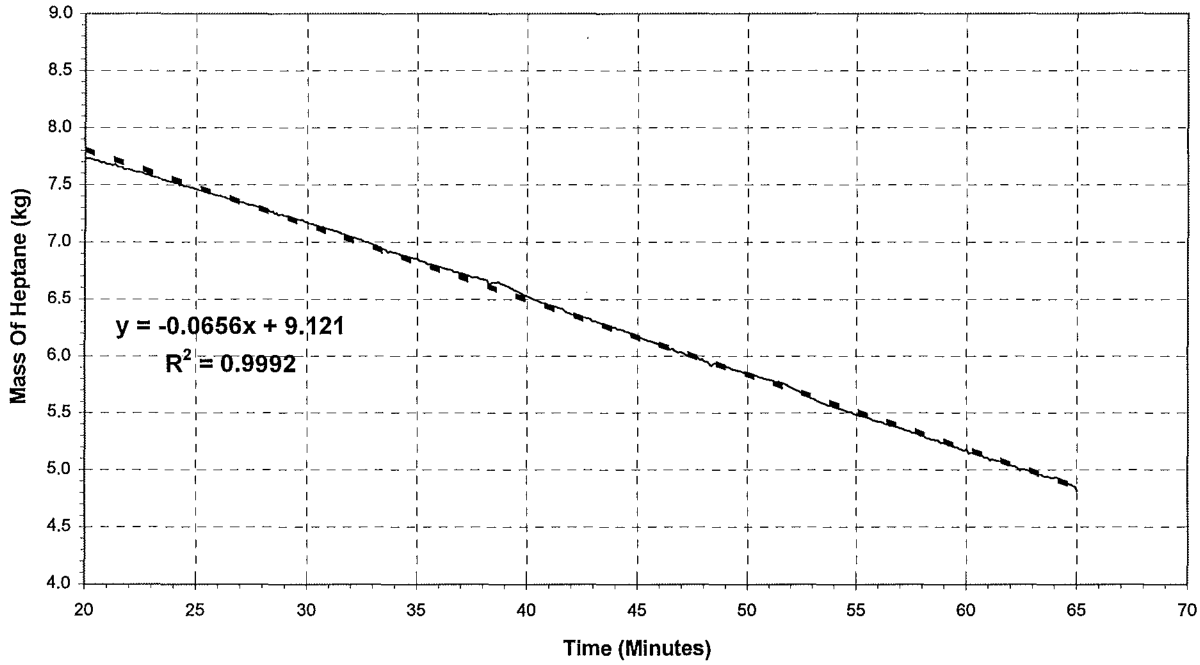
TEST #3

Ventilation Opening:	Height - Full Width - $^{1}/_{16}$
Weather Conditions:	Average wind speed = 1.9 m/s Maximum wind speed = 4.3 m/s

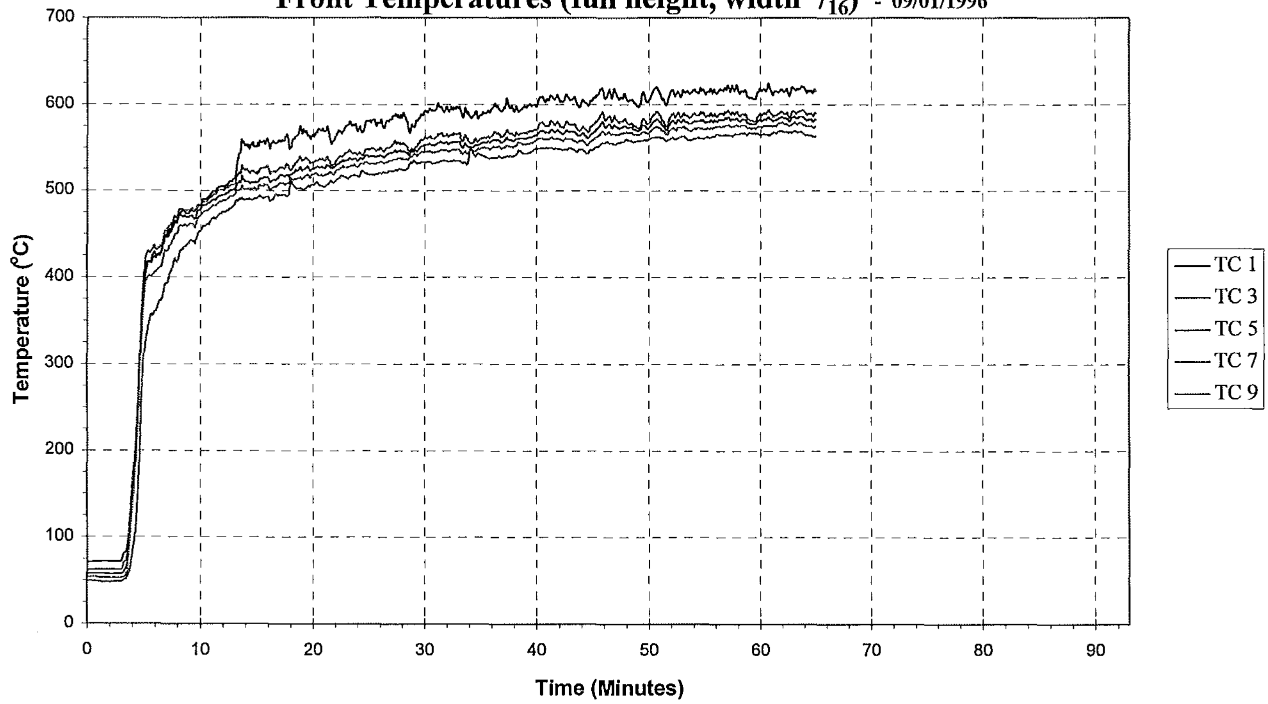
Comments: Experiment was only conducted for 65 minutes instead of 90 minutes, due to the onset rain.

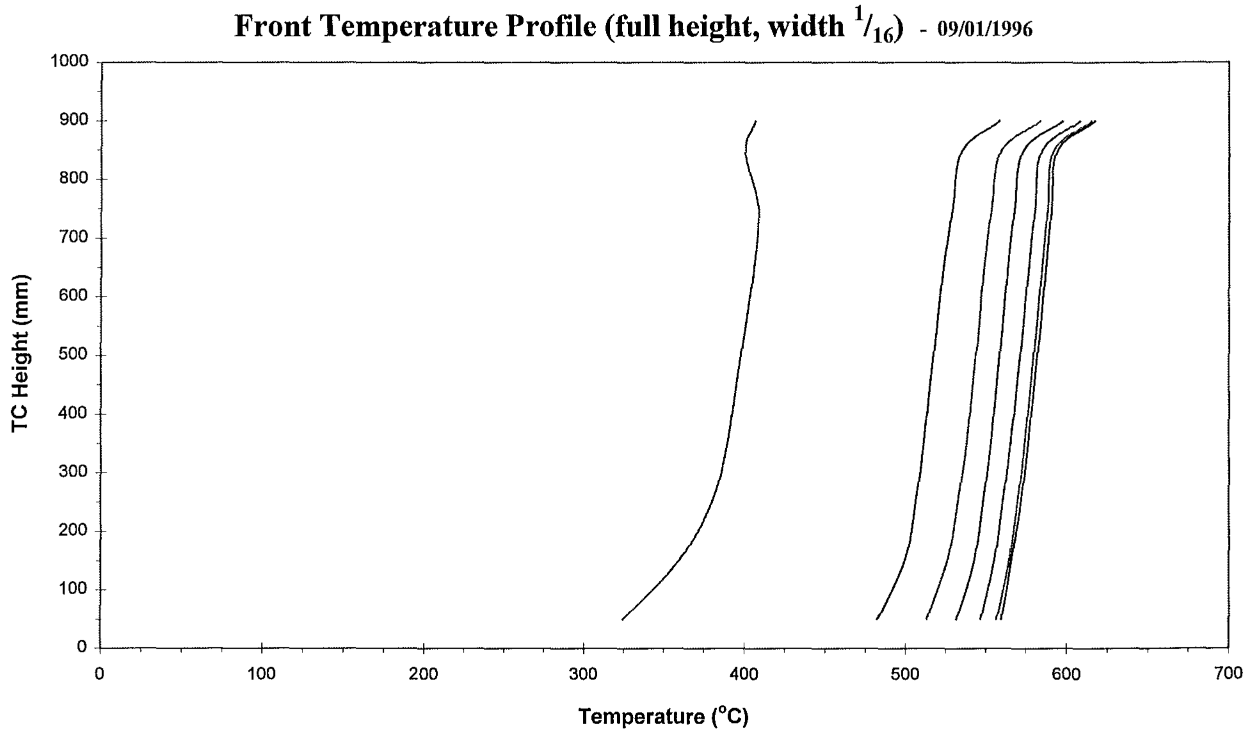


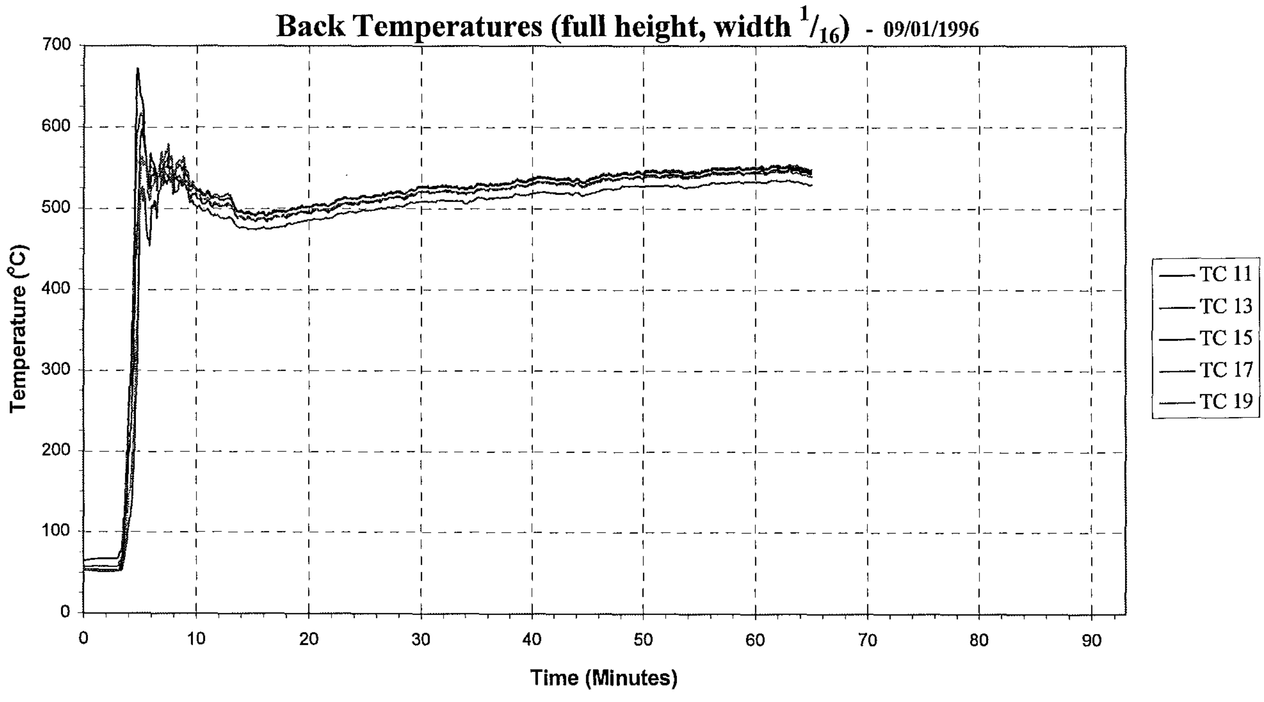
Mass Loss Rate (full height, width $^1/_{16}$) - 09/01/1996

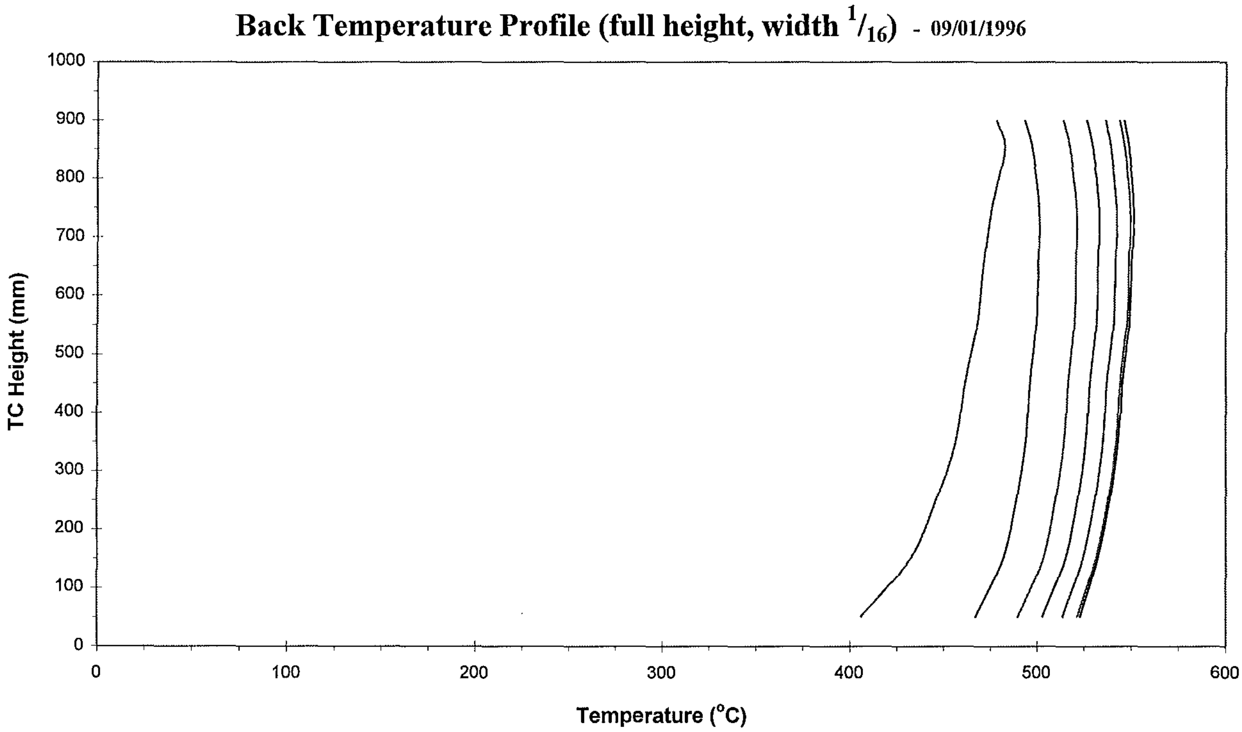


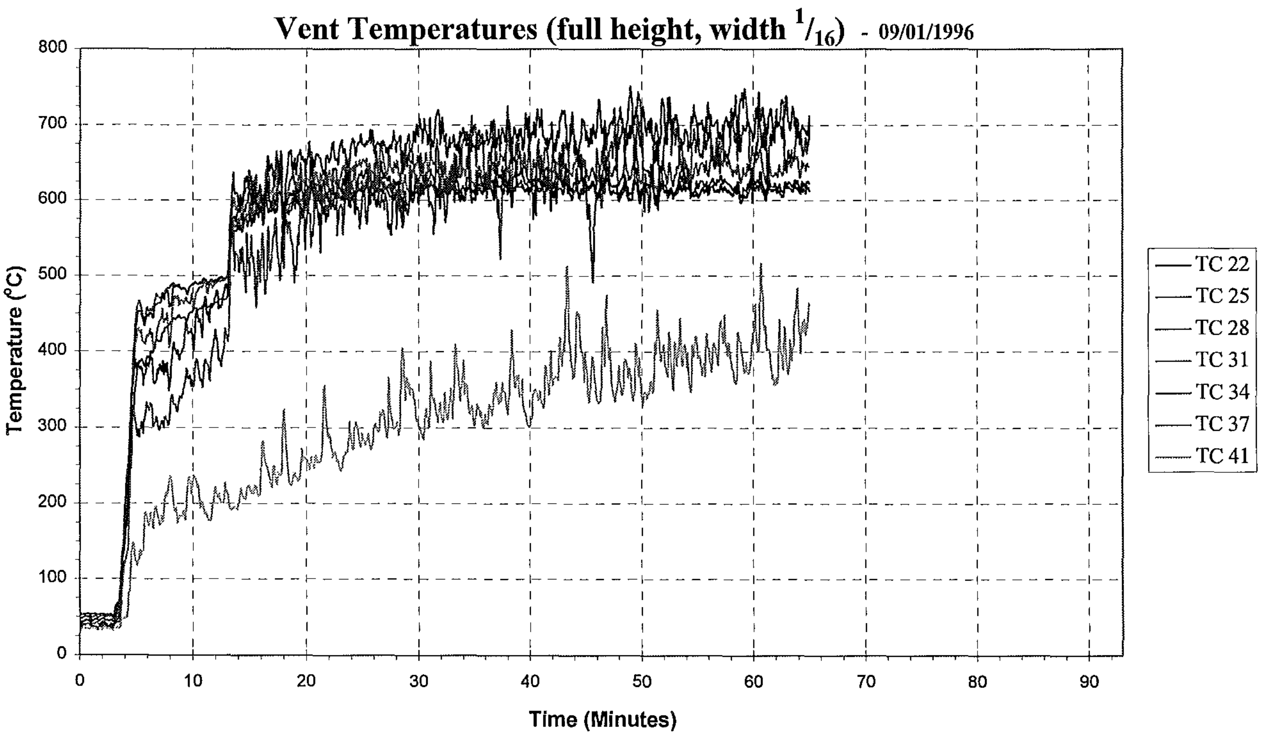
Front Temperatures (full height, width $^1/_{16}$) - 09/01/1996

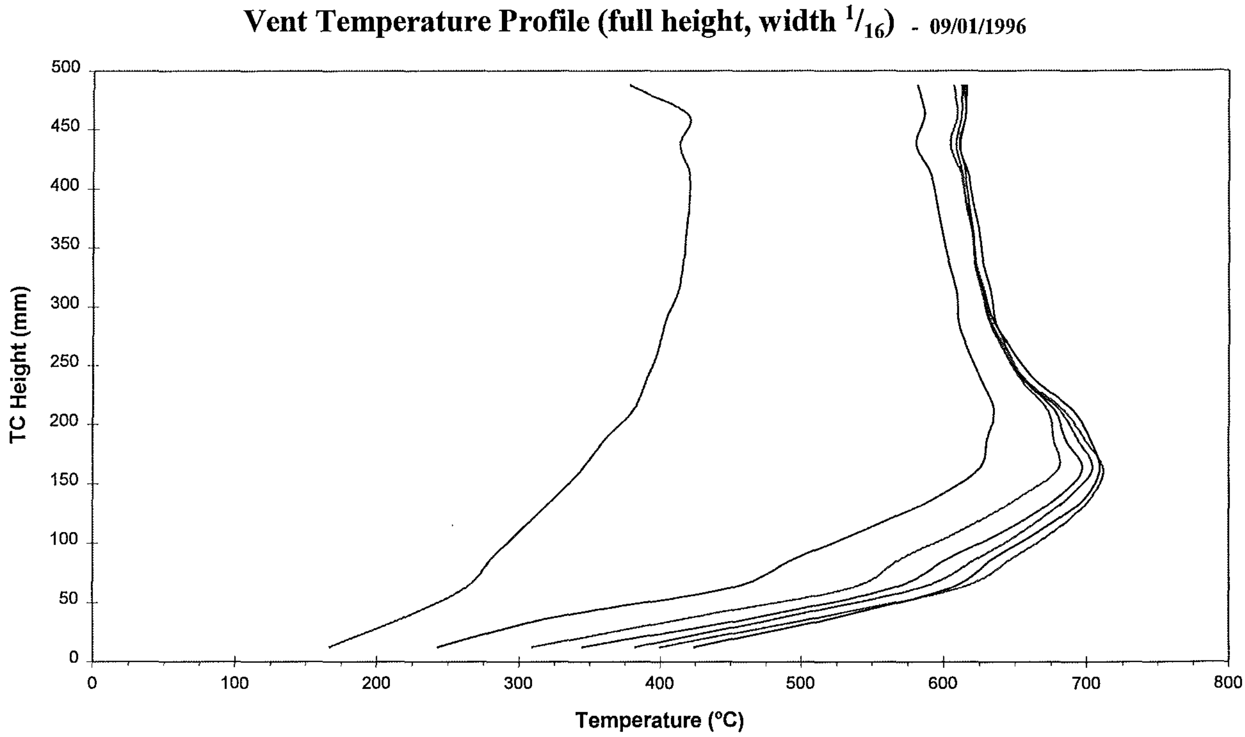


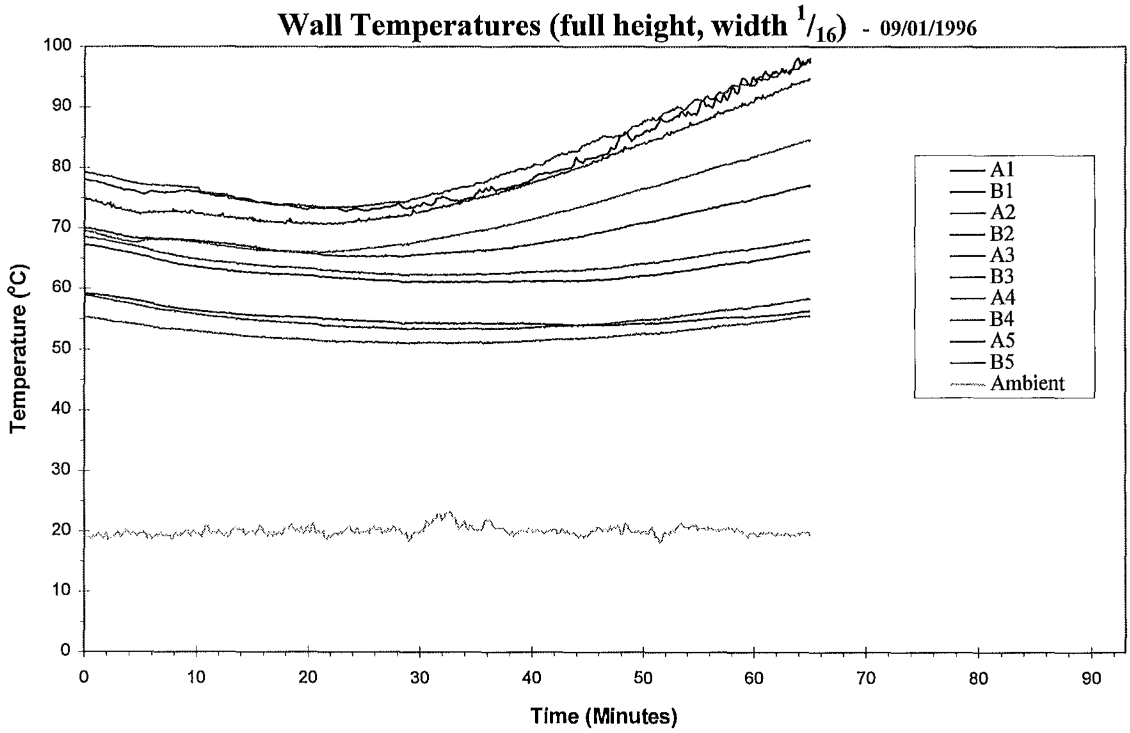

Front Temperature Profile (full height, width 1/16) - 09/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
Temperature (°C)


Back Temperatures (full height, width 1/16) - 09/01/1996
Temperature (°C)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19


Back Temperature Profile (full height, width 1/16) - 09/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
Temperature (°C)


Vent Temperatures (full height, width 1/16) - 09/01/1996
Temperature (°C)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41


Vent Temperature Profile (full height, width 1/16) - 09/01/1996
TC Height (mm)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Temperature (°C)


Wall Temperatures (full height, width 1/16) - 09/01/1996
Temperature (°C)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient

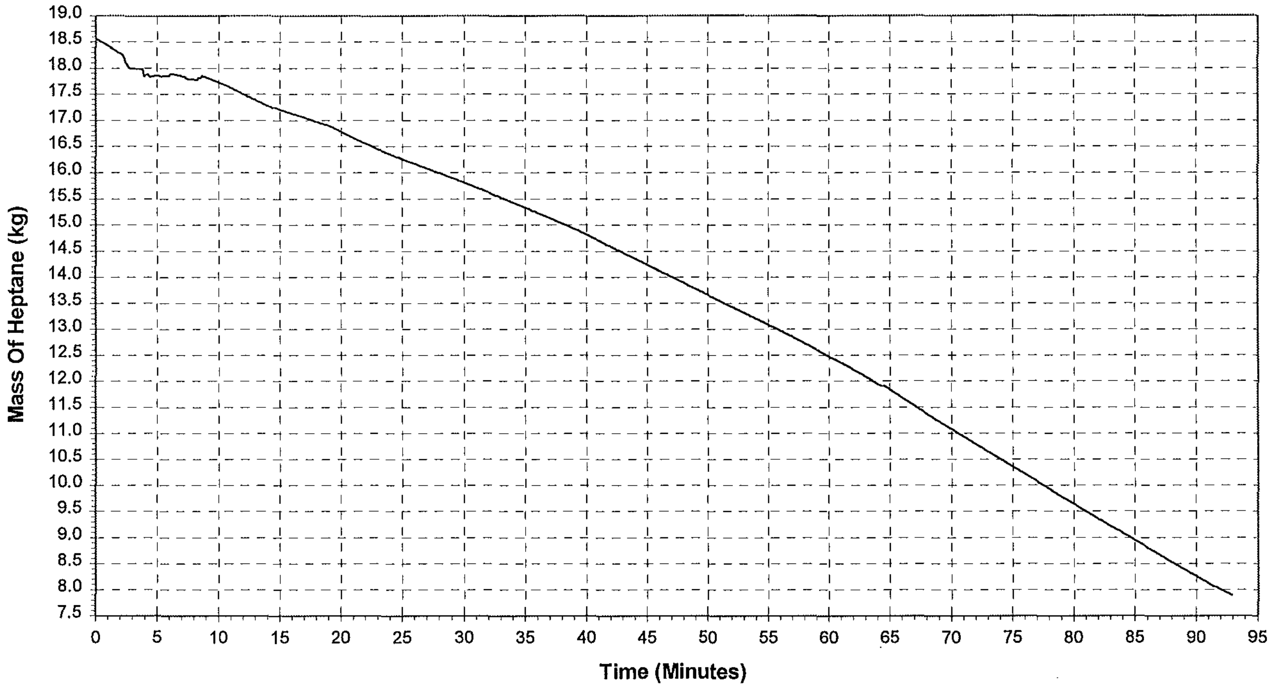
TEST #4

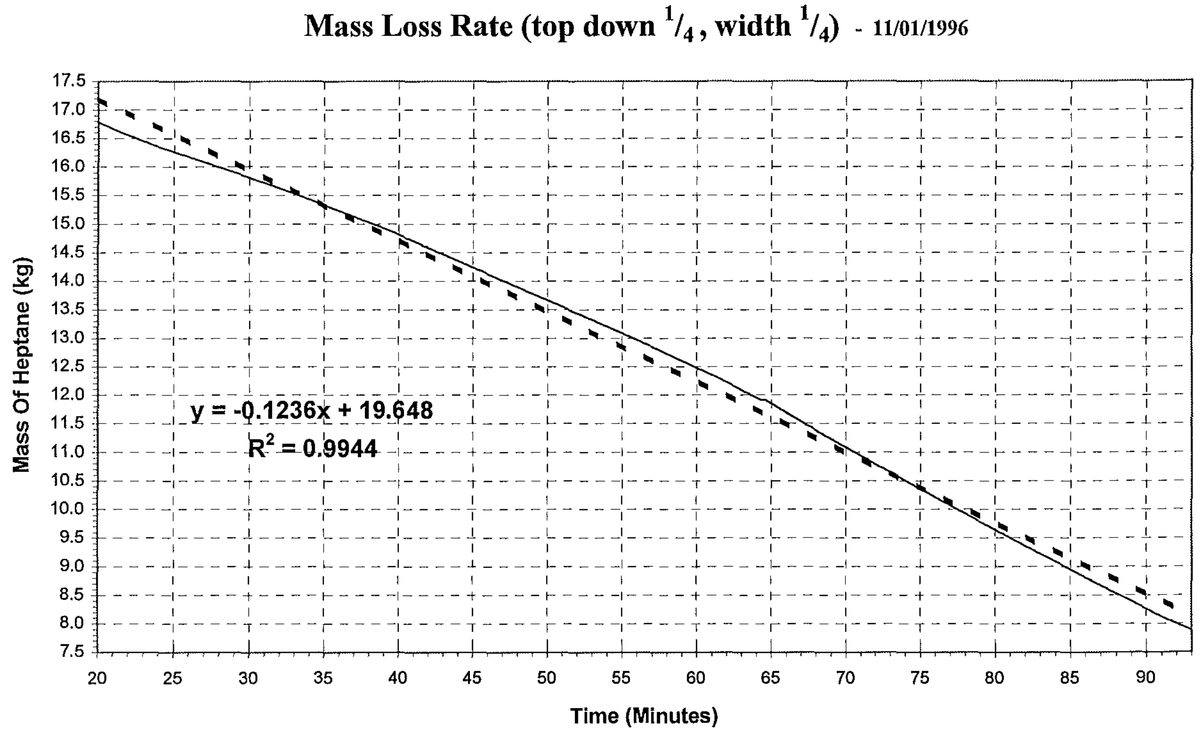
Ventilation Opening: Height - Top down $^1/_4$
Width - $^1/_4$

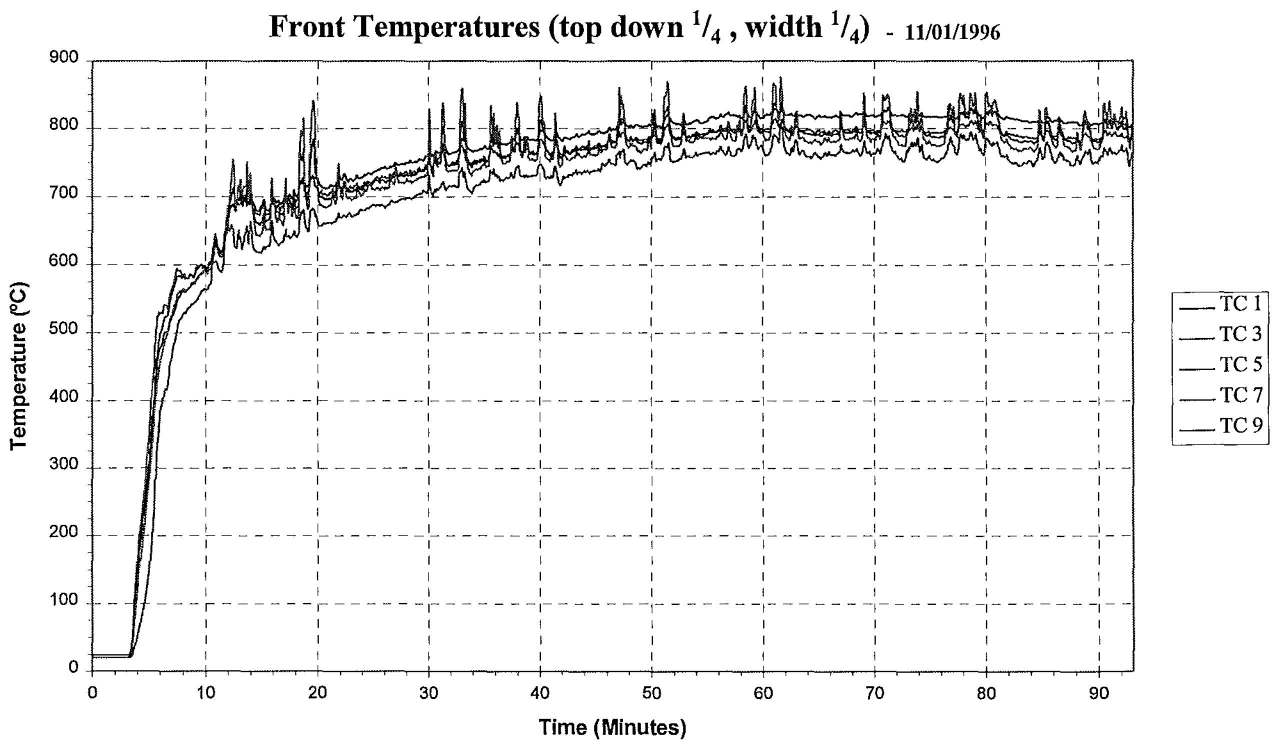
Weather Conditions: Average wind speed = 1.2 m/s
Maximum wind speed = 2.2 m/s

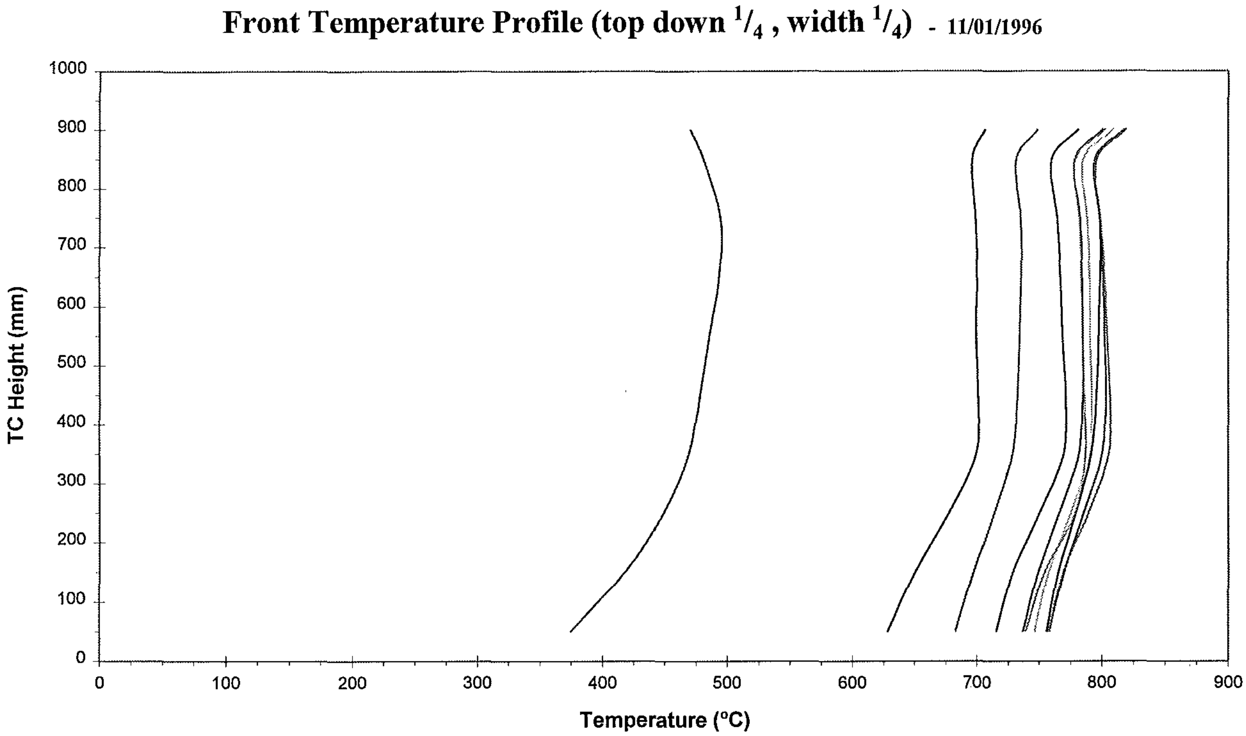
Comments:

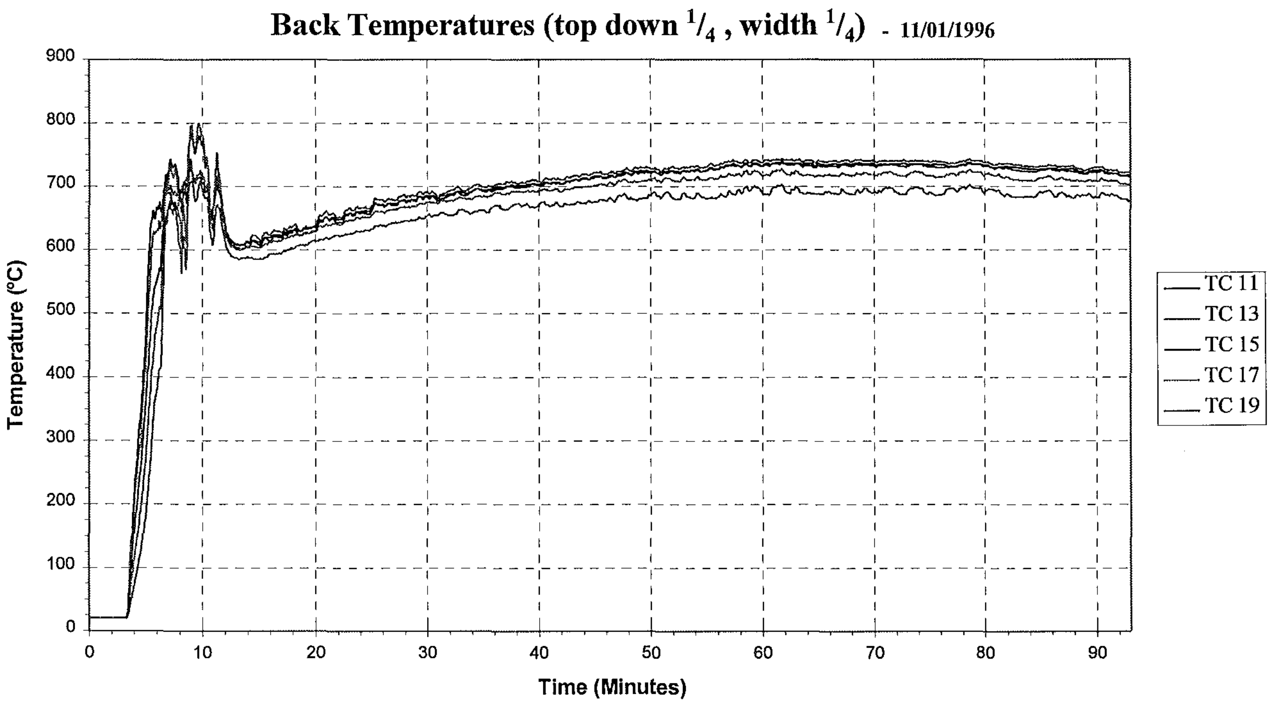
Heptane Mass Loss (top down $^1/_4$, width $^1/_4$) - 11/01/1996



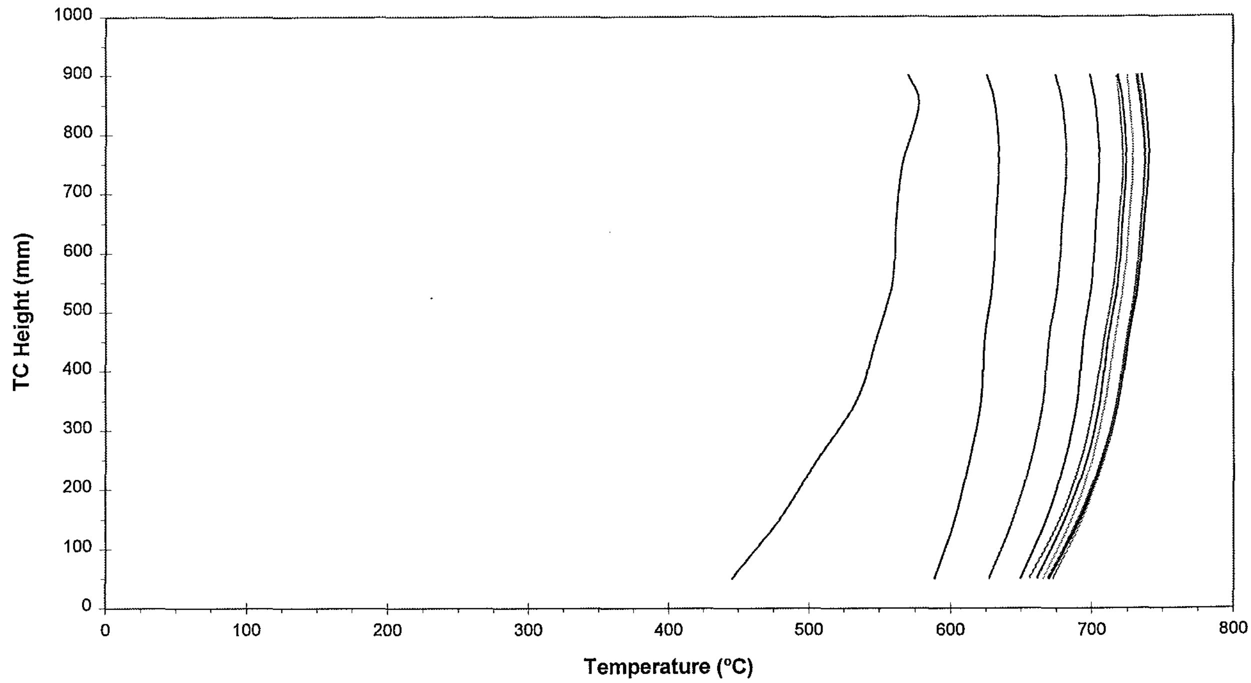

Mass Loss Rate (top down 1/4, width 1/4) - 11/01/1996
Mass Of Heptane (kg)
Time (Minutes)
y = -0.1236x + 19.648
R² = 0.9944
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90


Front Temperatures (top down 1/4, width 1/4) - 11/01/1996
Temperature (°C)
Time (Minutes)
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
TC 1
TC 3
TC 5
TC 7
TC 9

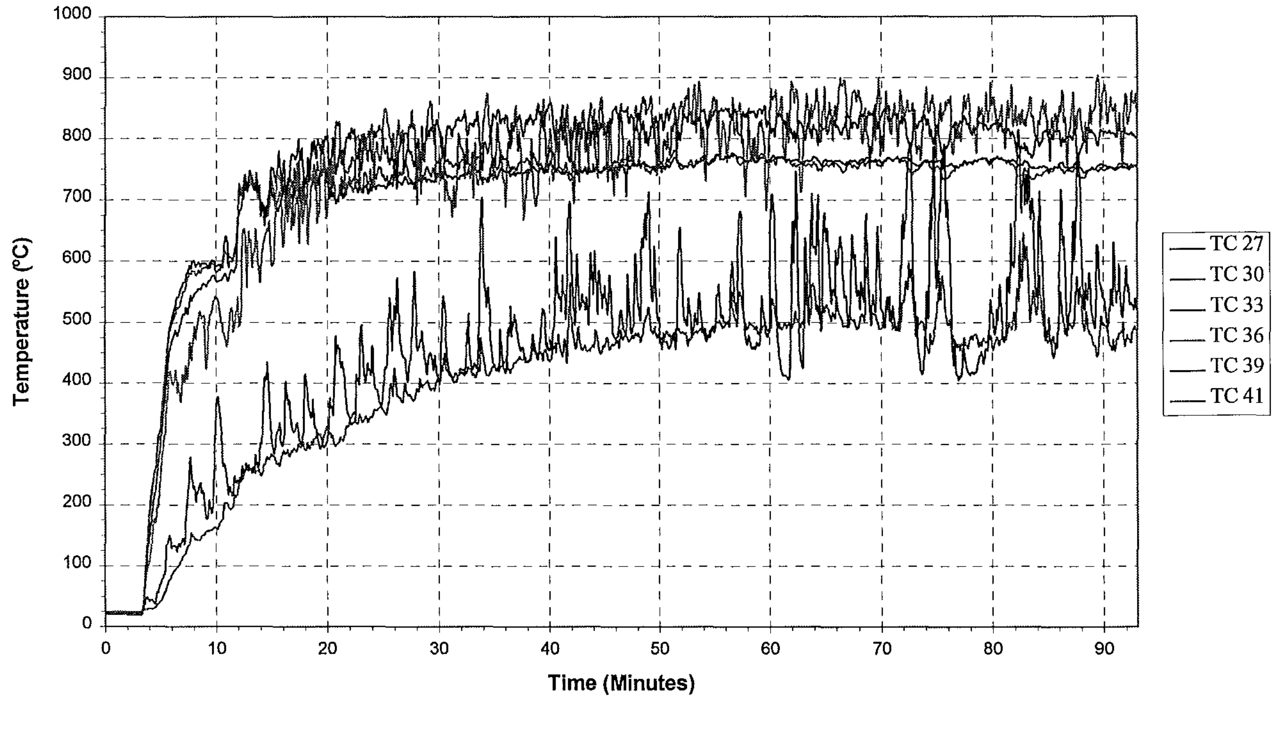

Front Temperature Profile (top down 1/4 , width 1/4) - 11/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000

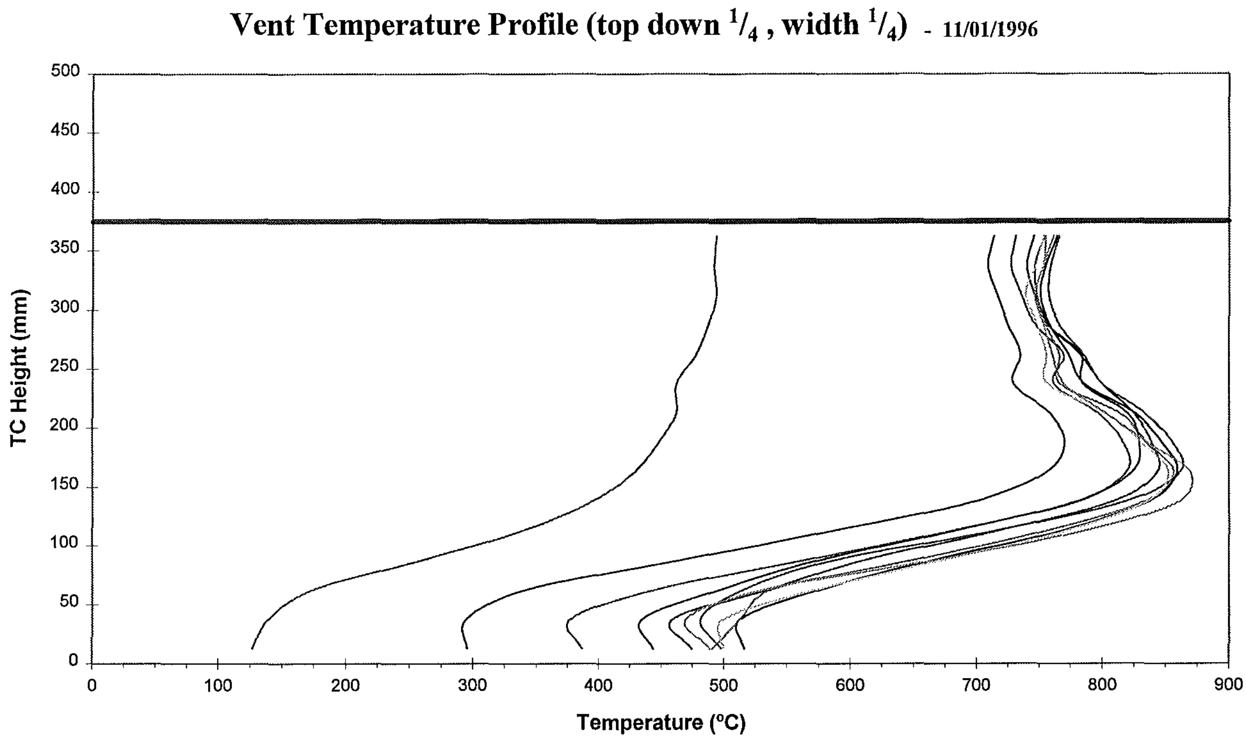

Back Temperatures (top down 1/4 , width 1/4) - 11/01/1996
Temperature (°C)
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19
0
10
20
30
40
50
60
70
80
90

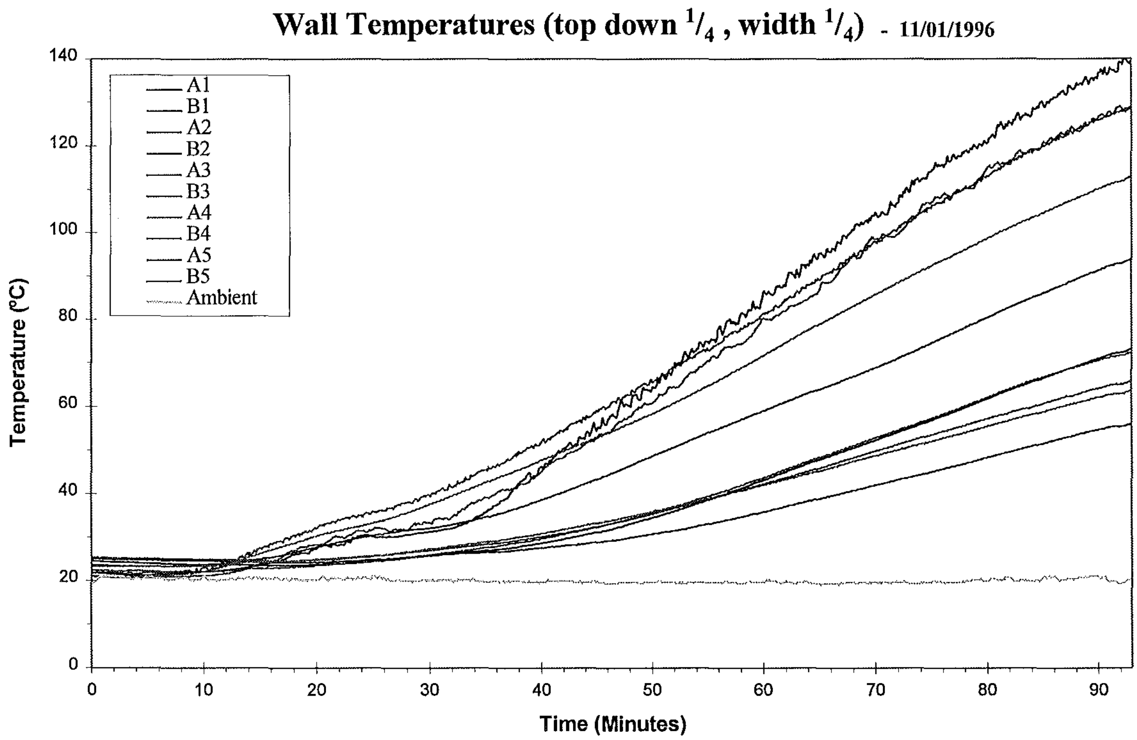
Back Temperature Profile (top down 1/4 , width 1/4) - 11/01/1996



Vent Temperatures (top down 1/4 , width 1/4) - 11/01/1996




Vent Temperature Profile (top down 1/4 , width 1/4) - 11/01/1996
500
450
400
350
300
250
200
150
100
50
0
TC Height (mm)
0
100
200
300
400
500
600
700
800
900
Temperature (°C)

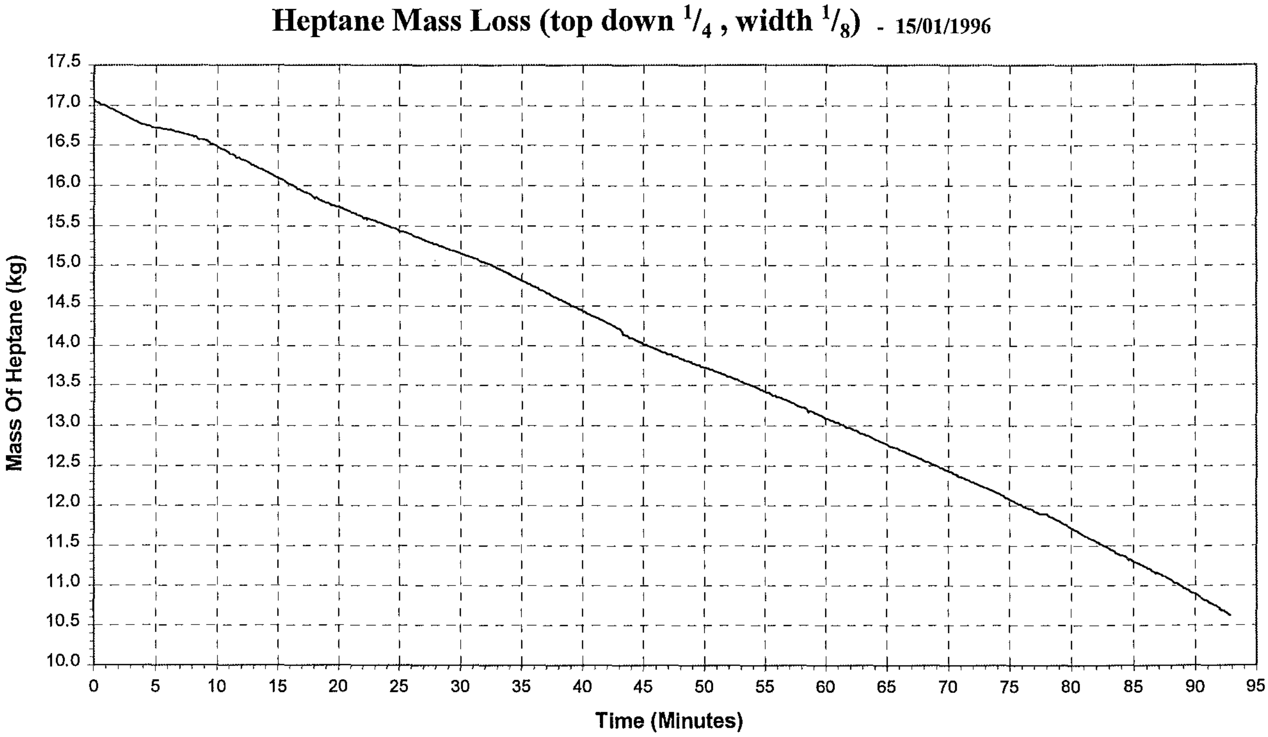

Wall Temperatures (top down 1/4 , width 1/4) - 11/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
140
120
100
80
60
40
20
0
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
Time (Minutes)

TEST #5

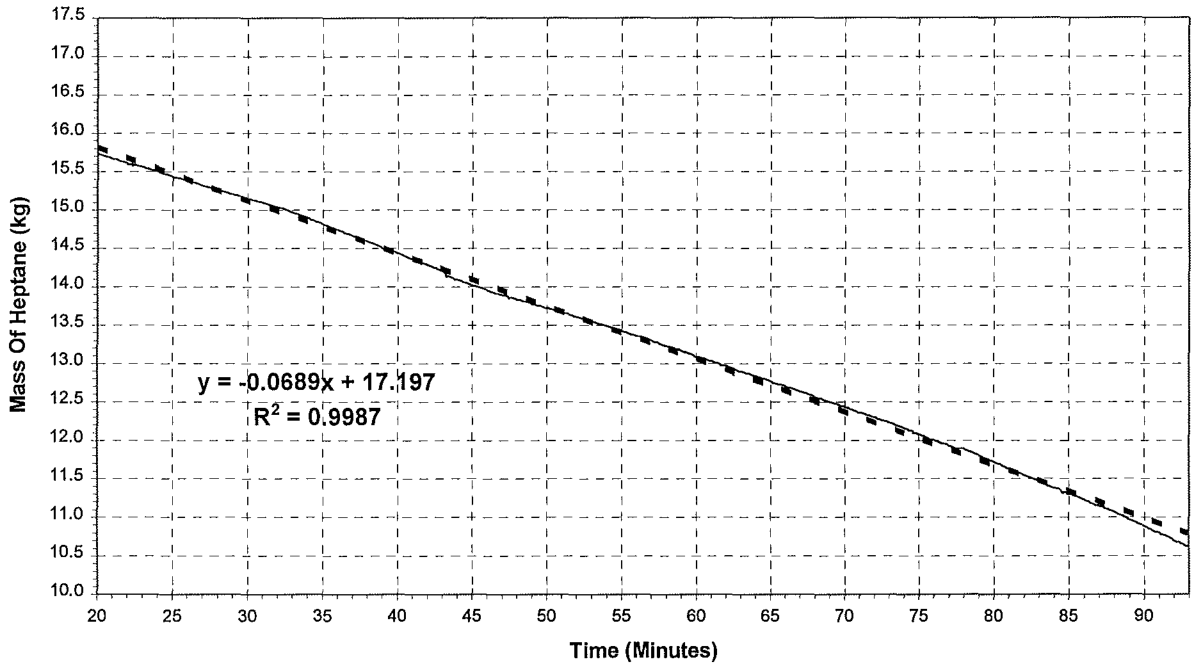
Ventilation Opening: Height - Top down $^1/_4$
Width - $^1/_8$

Weather Conditions: Average wind speed = 1.2 m/s
Maximum wind speed = 3.4 m/s

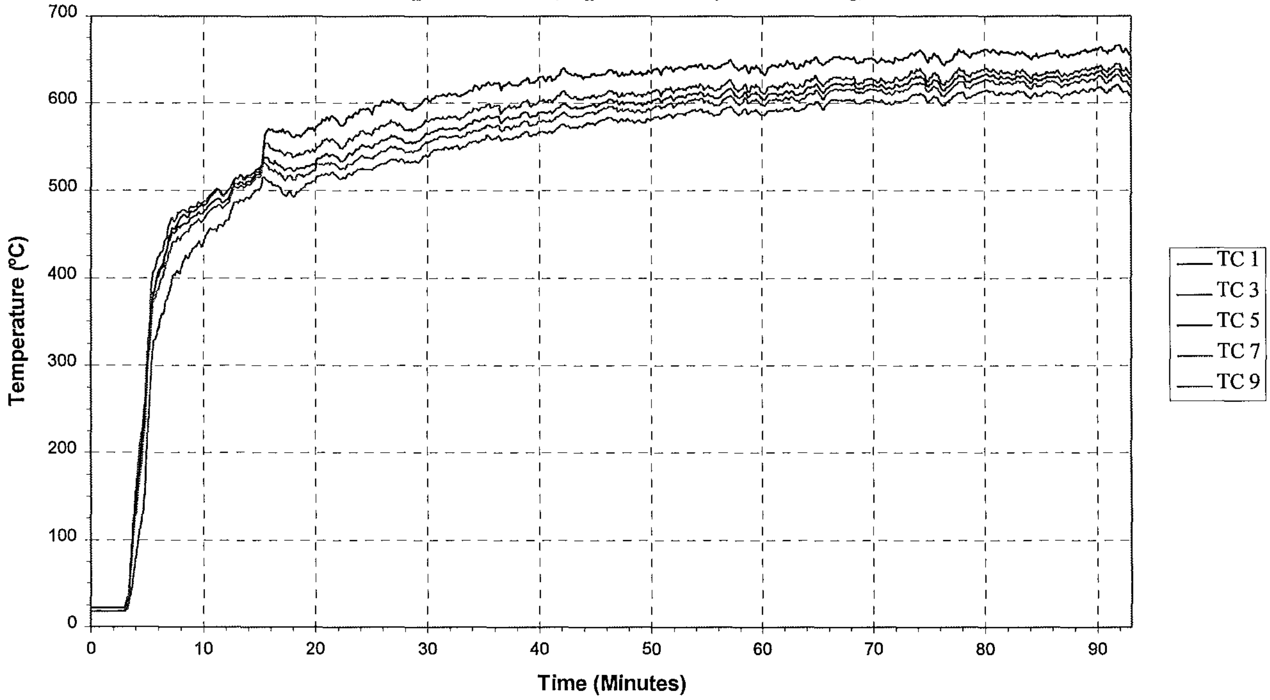
Comments:



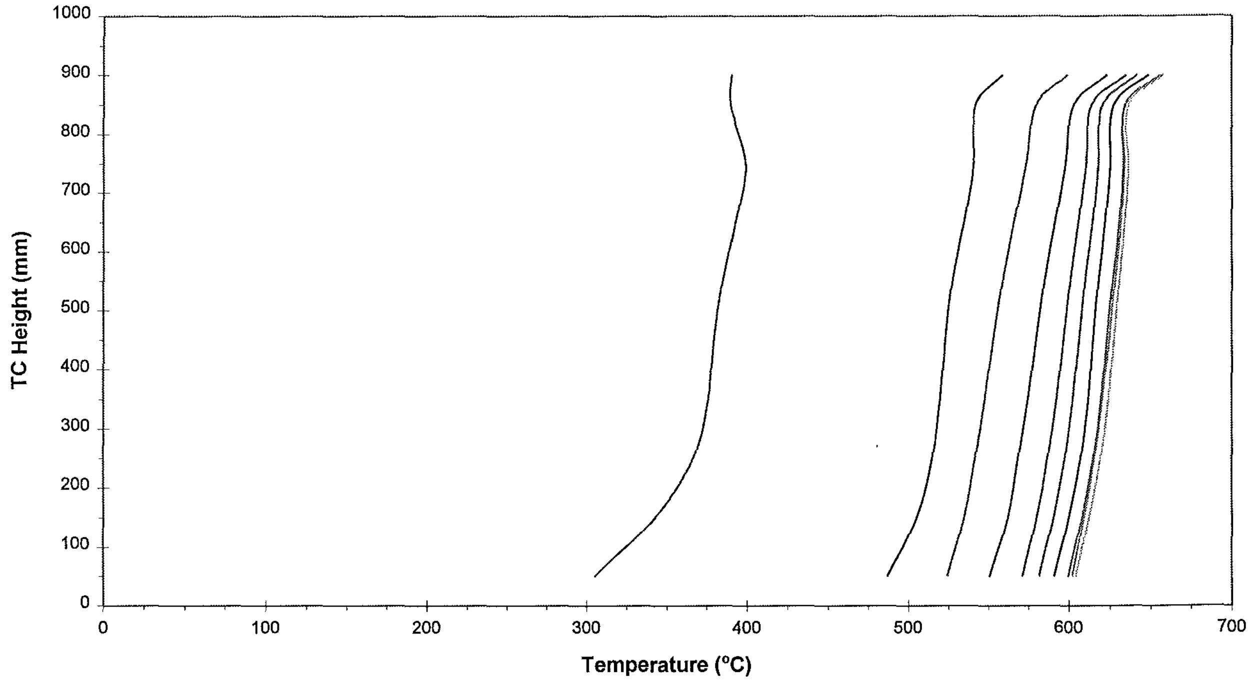
Mass Loss Rate (top down $^1/_4$, width $^1/_8$) - 15/01/1996



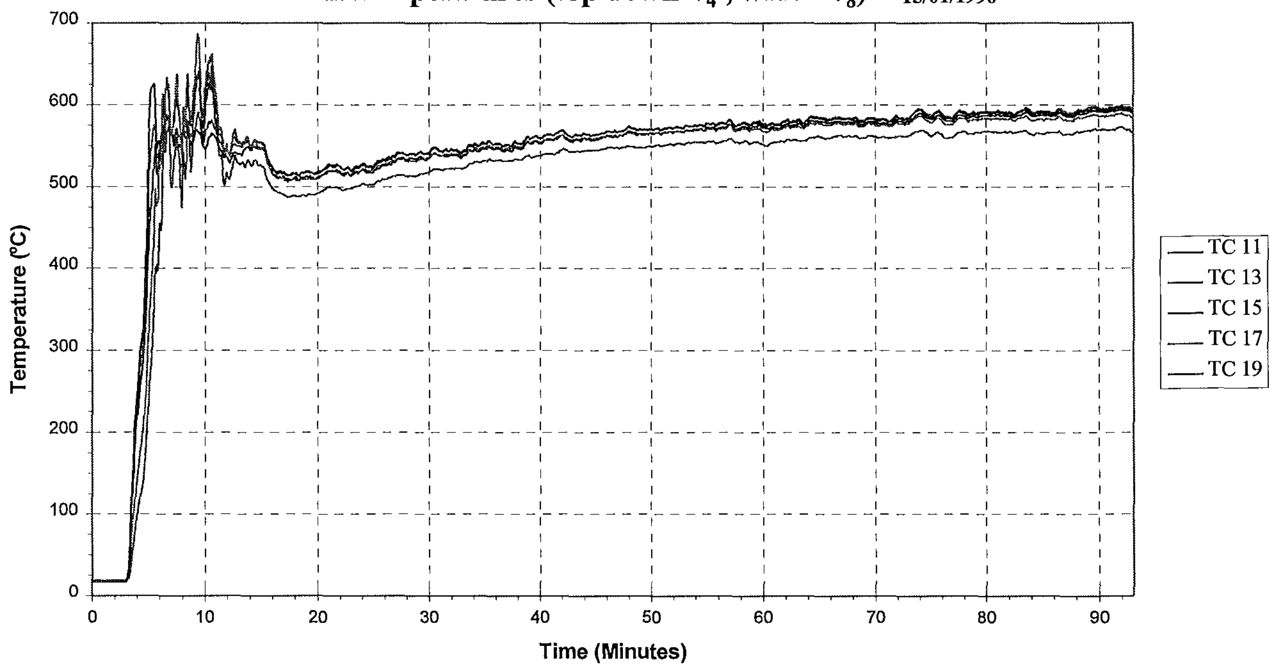
Front Temperatures (top down $^1/_4$, width $^1/_8$) - 15/01/1996

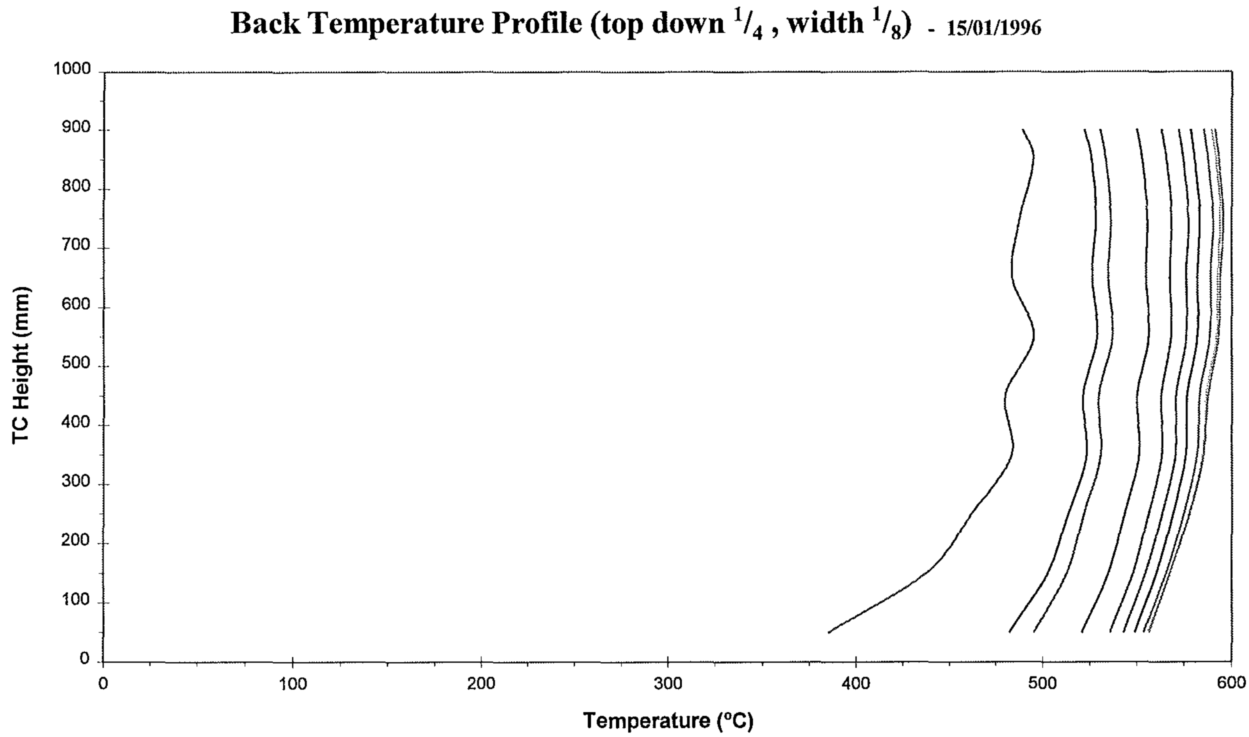


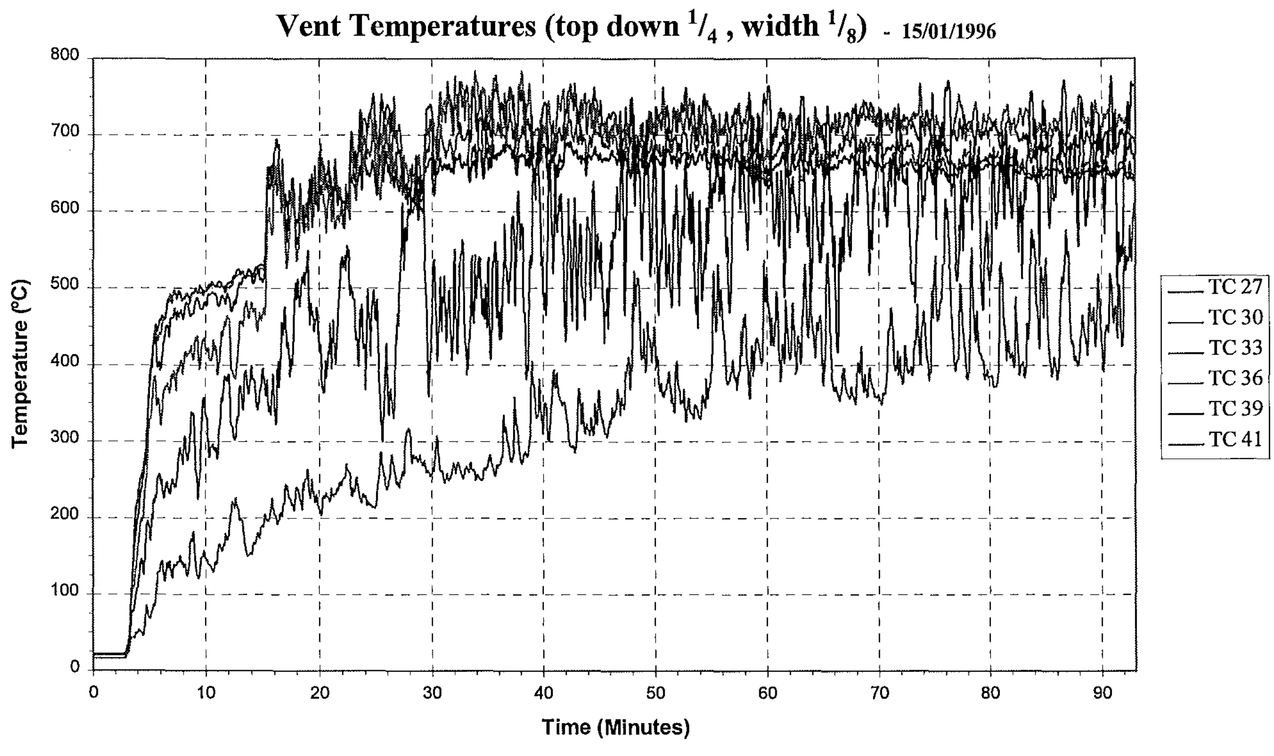
Front Temperature Profile (top down $^1/_4$, width $^1/_8$) - 15/01/1996

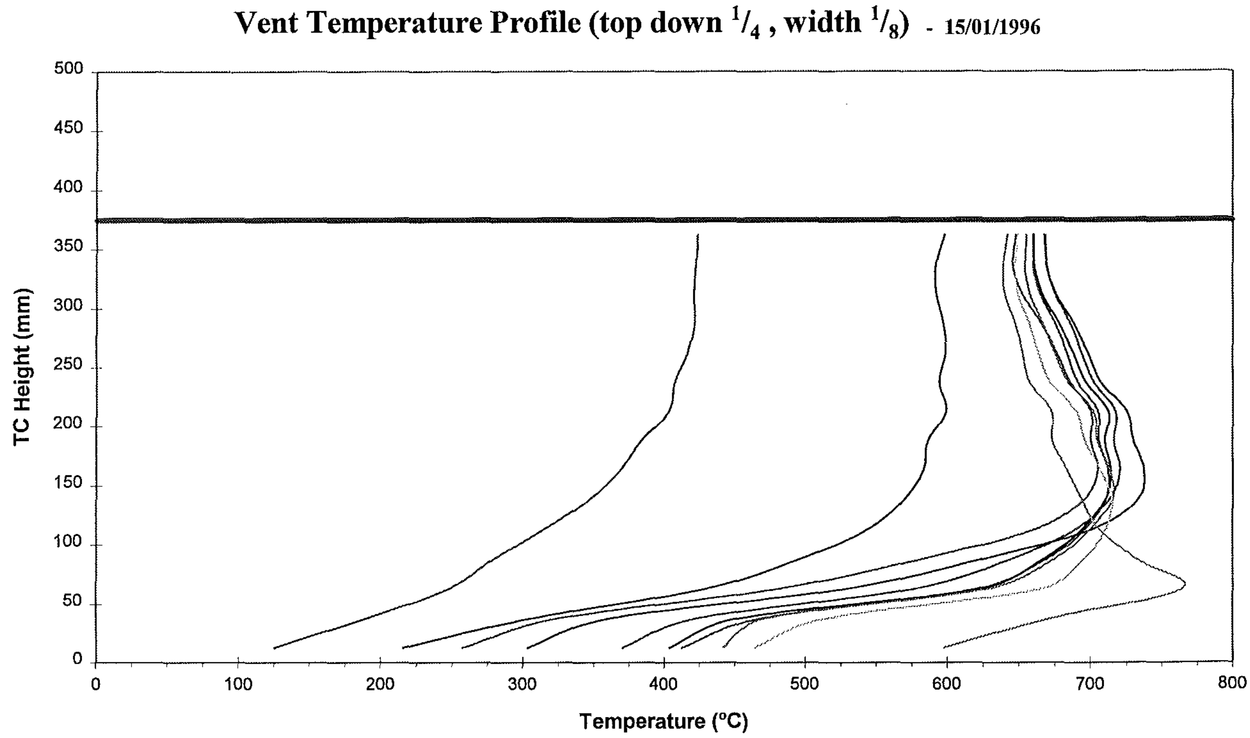


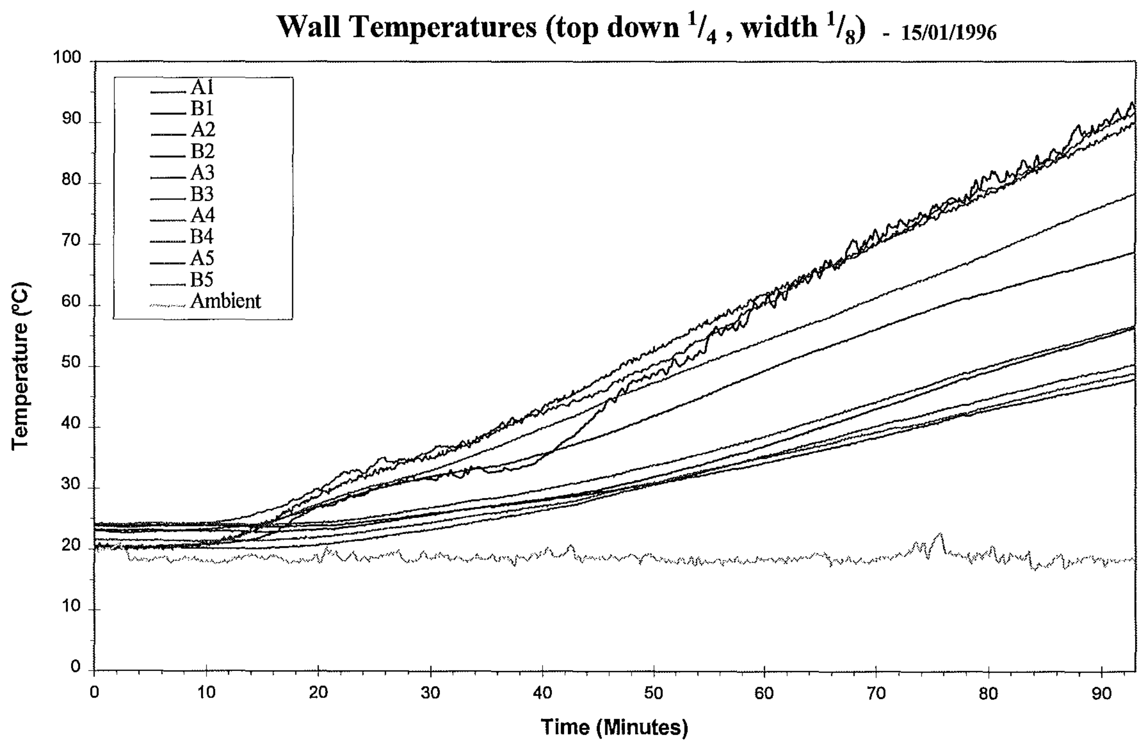
Back Temperatures (top down $^1/_4$, width $^1/_8$) - 15/01/1996




Back Temperature Profile (top down 1/4 , width 1/8) - 15/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
Temperature (°C)


Vent Temperatures (top down 1/4 , width 1/8) - 15/01/1996
Temperature (°C)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 27
TC 30
TC 33
TC 36
TC 39
TC 41


Vent Temperature Profile (top down 1/4 , width 1/8) - 15/01/1996
TC Height (mm)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Temperature (°C)

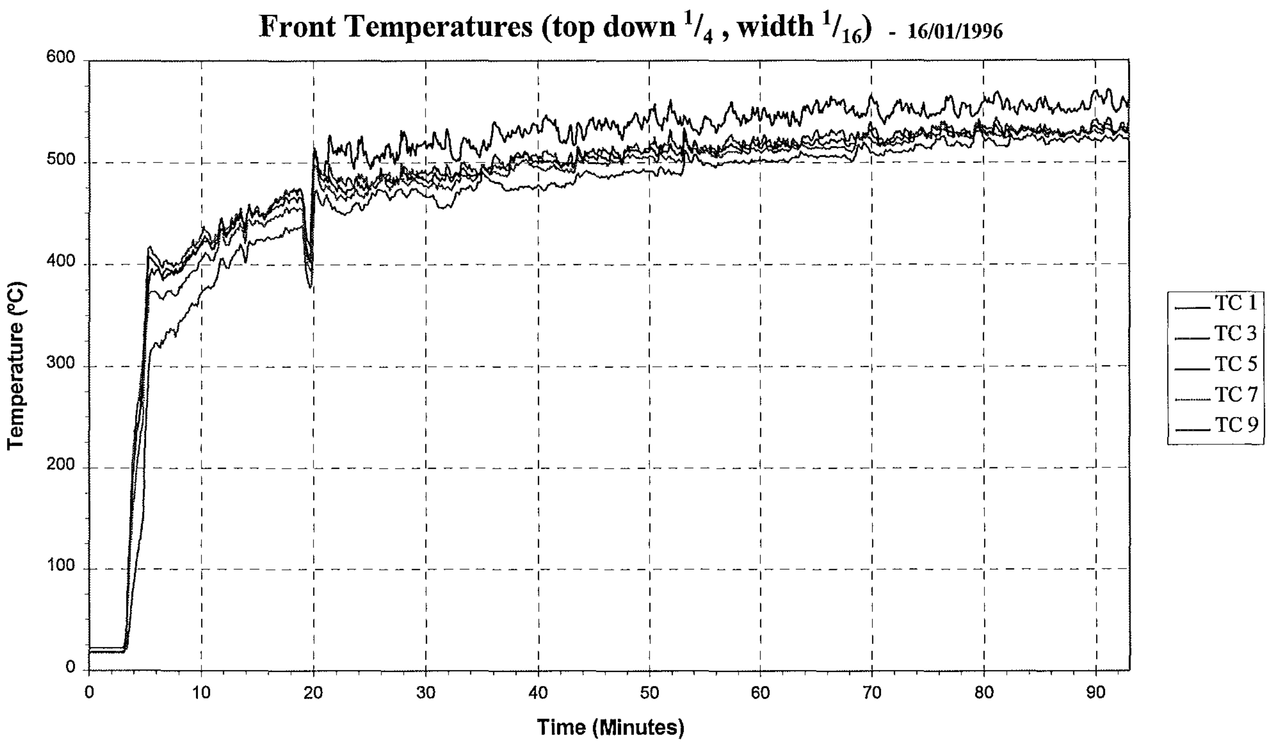

Wall Temperatures (top down 1/4 , width 1/8) - 15/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)

TEST #6

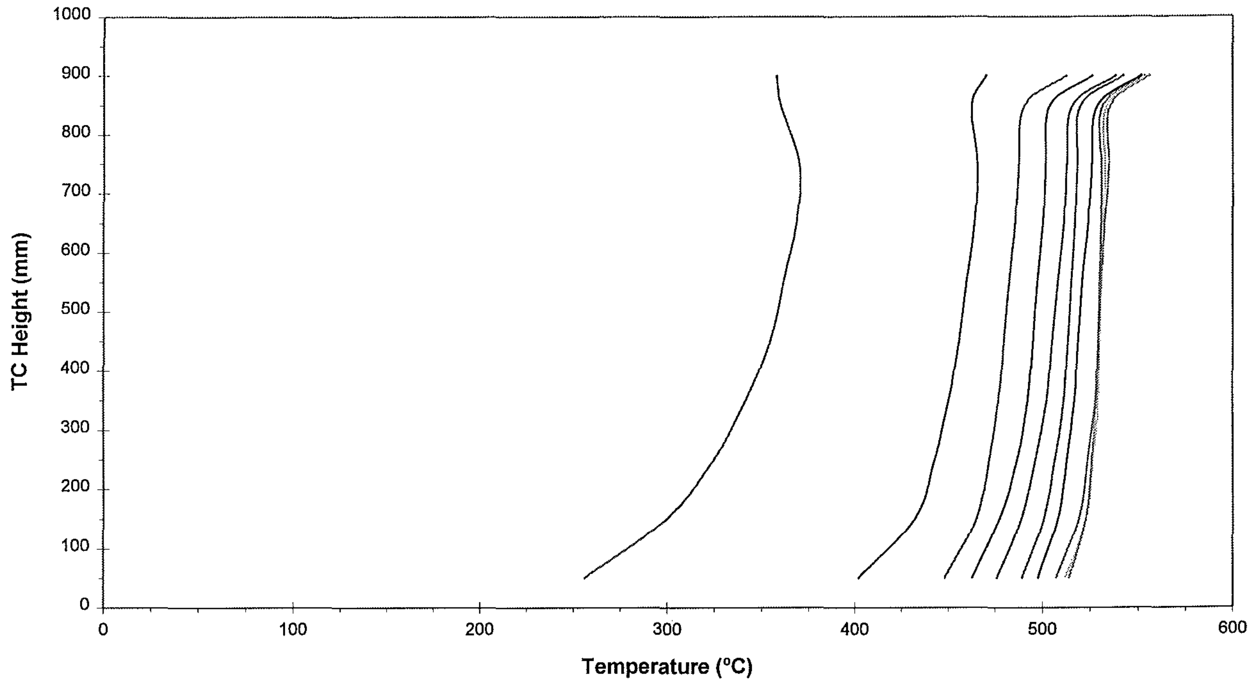
Ventilation Opening: Height - Top down $^1/_4$
Width - $^1/_{16}$

Weather Conditions: Average wind speed = 1.5 m/s
Maximum wind speed = 4.5 m/s

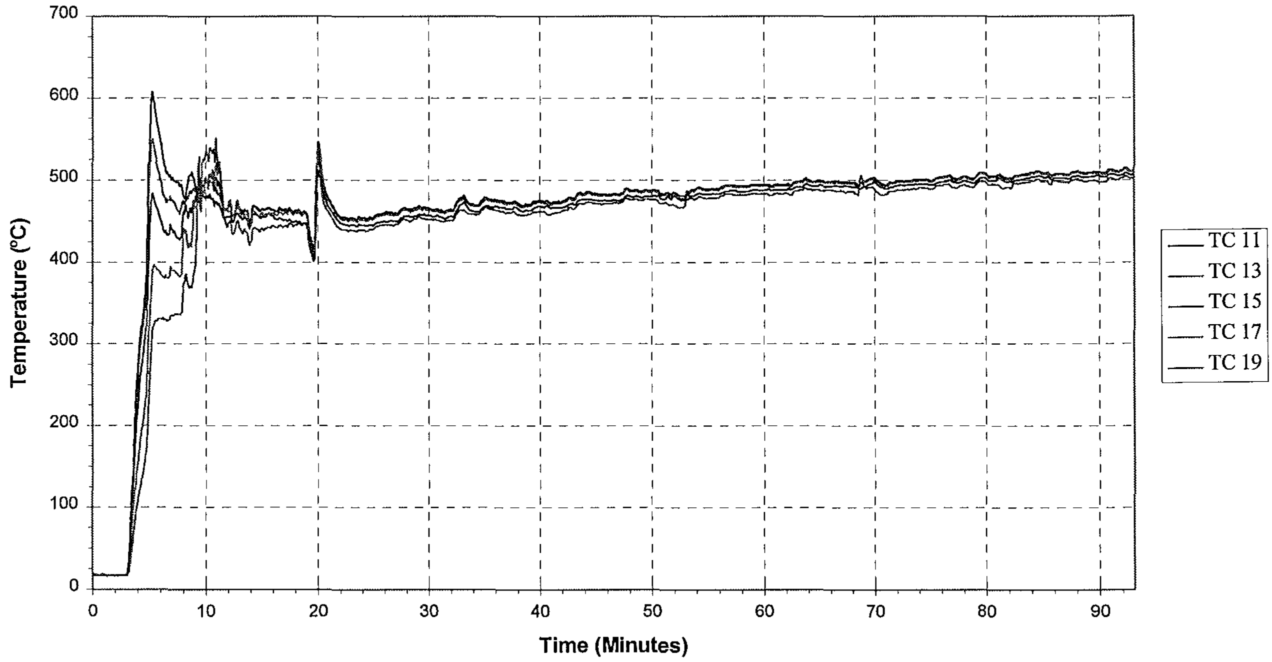
Comments: Mass Loss was not recorded.



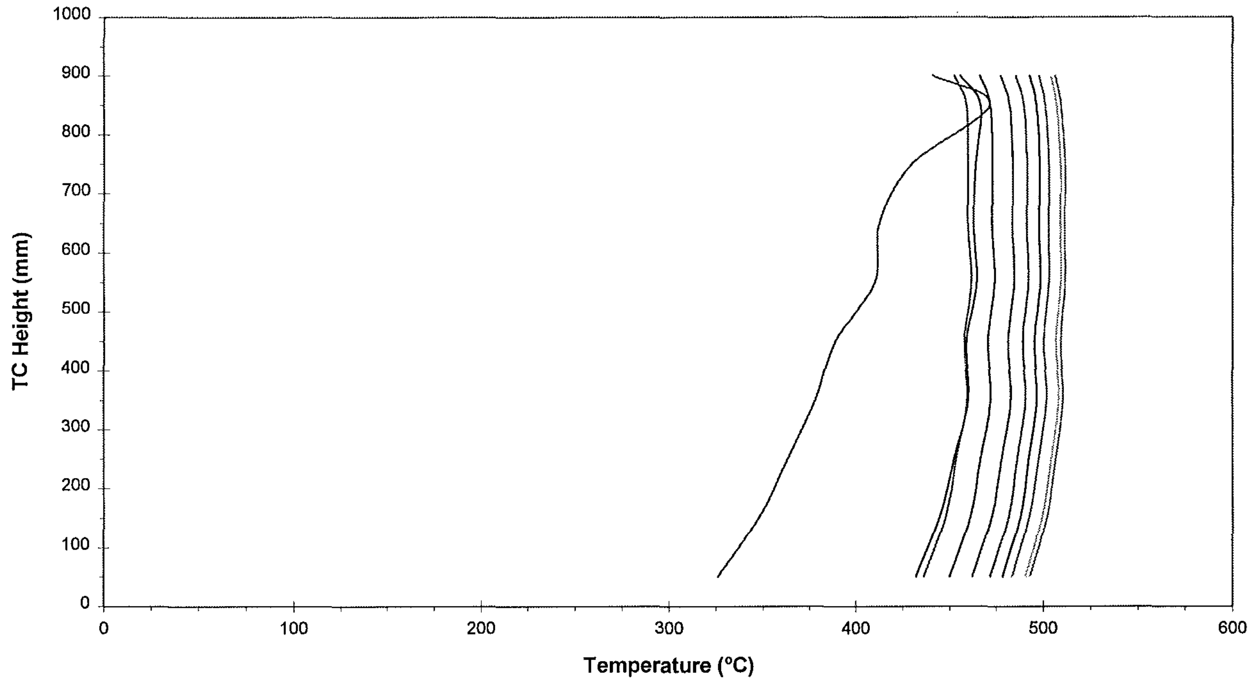
Front Temperature Profile (top down $^1/_4$, width $^1/_{16}$) - 16/01/1996



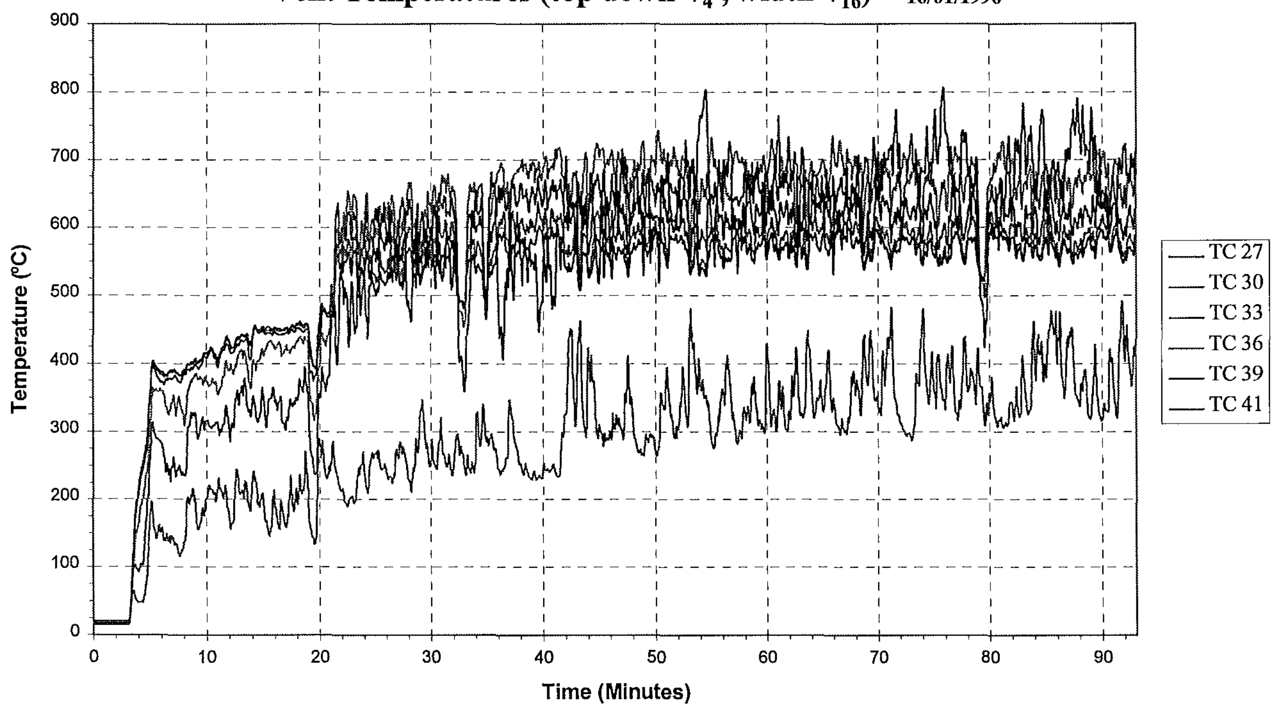
Back Temperatures (top down $^1/_4$, width $^1/_{16}$) - 16/01/1996

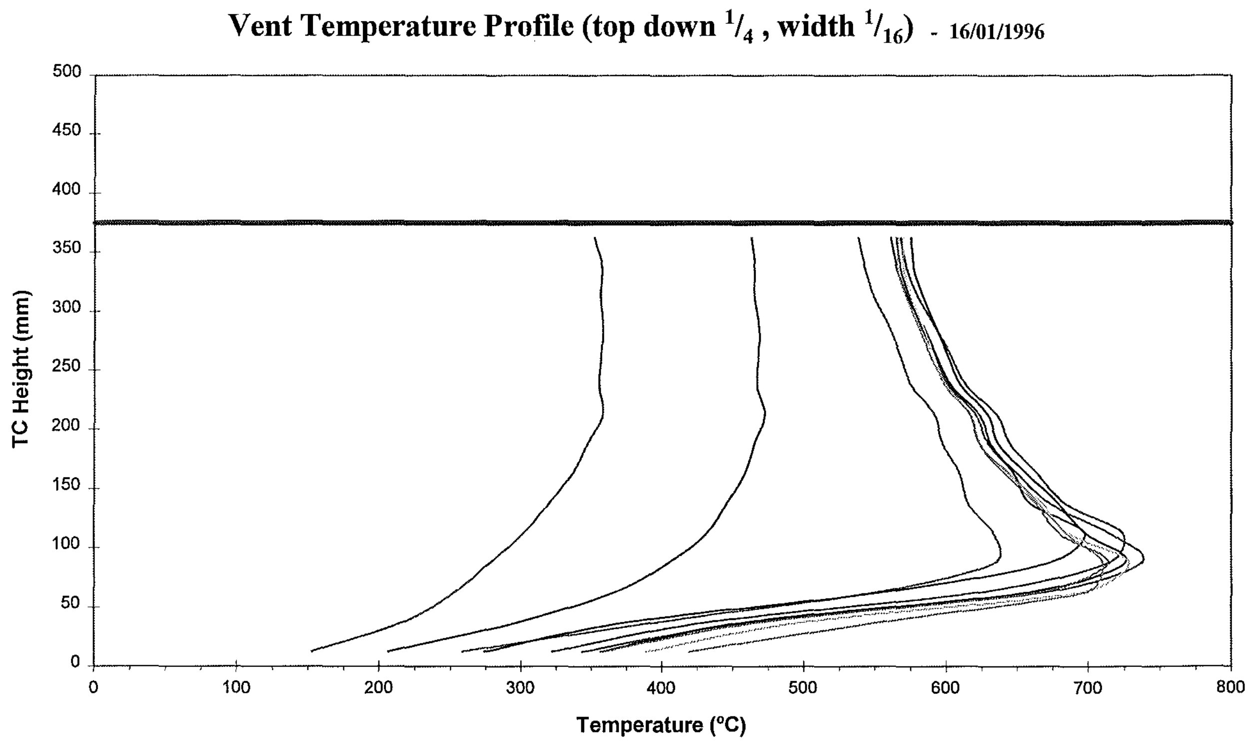


Back Temperature Profile (top down $^1/_4$, width $^1/_{16}$) - 16/01/1996

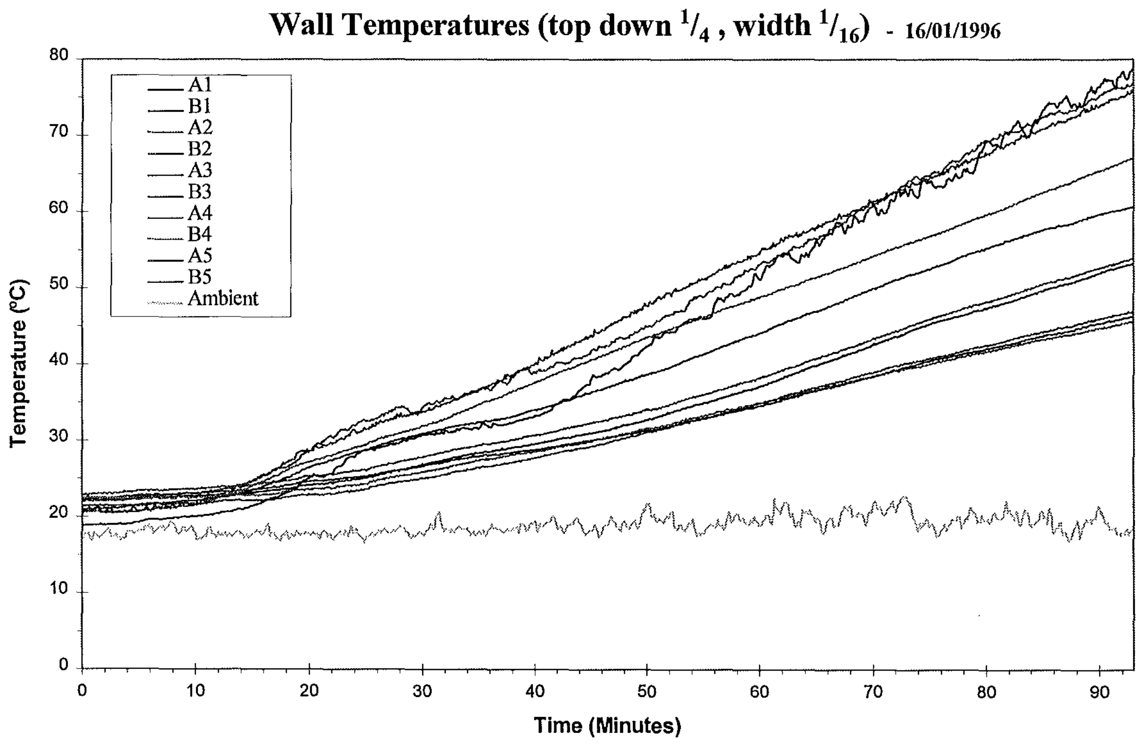


Vent Temperatures (top down $^1/_4$, width $^1/_{16}$) - 16/01/1996





Vent Temperature Profile (top down 1/4 , width 1/16) - 16/01/1996
TC Height (mm)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
Temperature (°C)



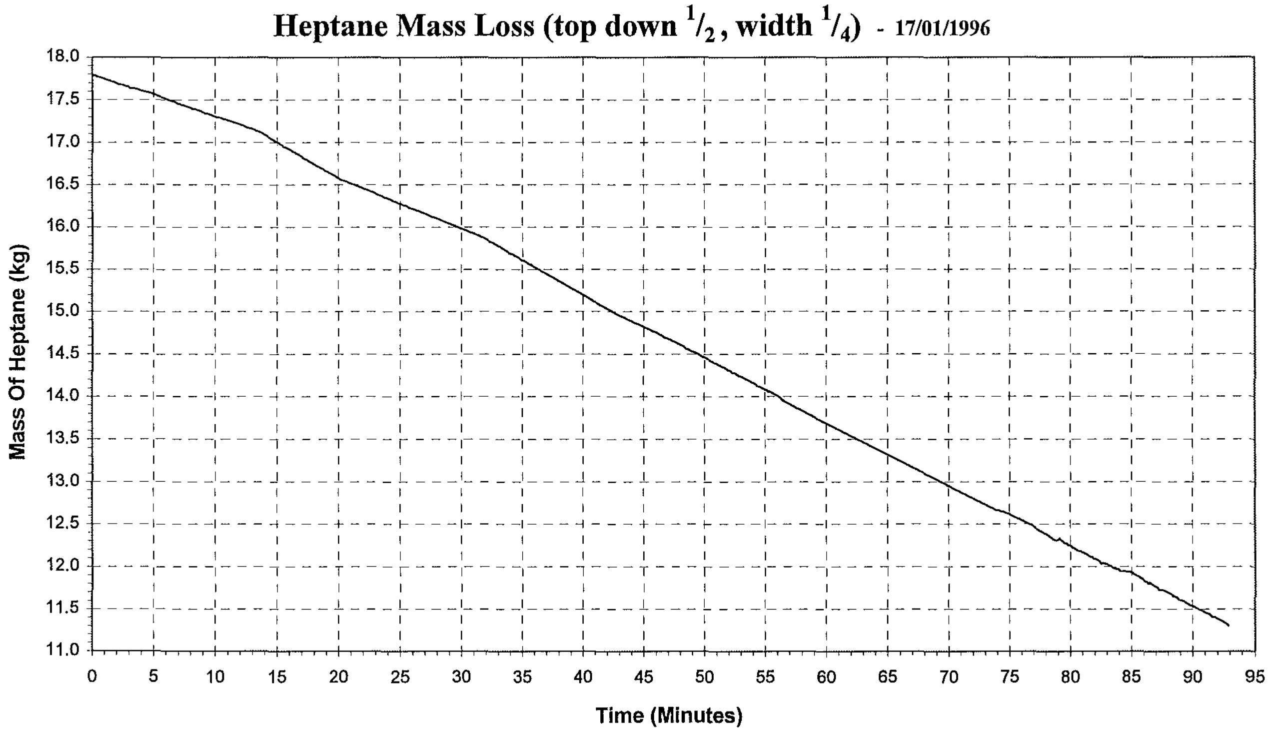
Wall Temperatures (top down 1/4 , width 1/16) - 16/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)

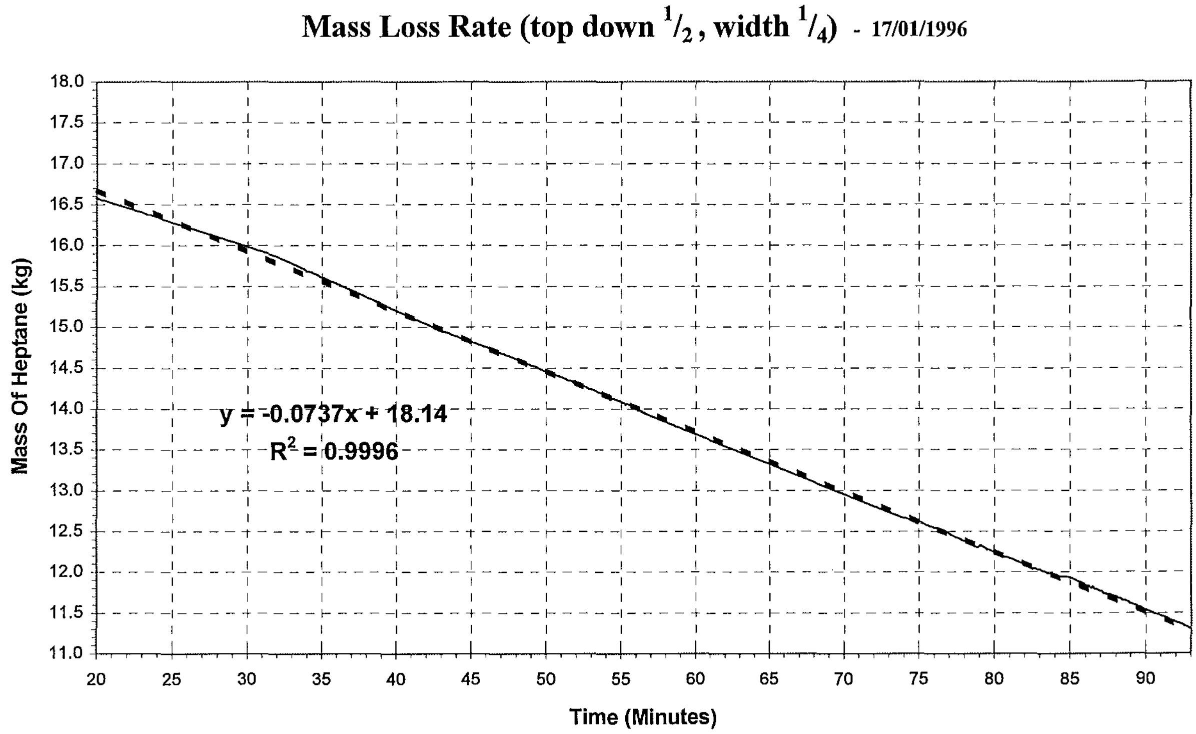
TEST #7

Ventilation Opening: Height - Top down $^1/_2$
Width - $^1/_4$

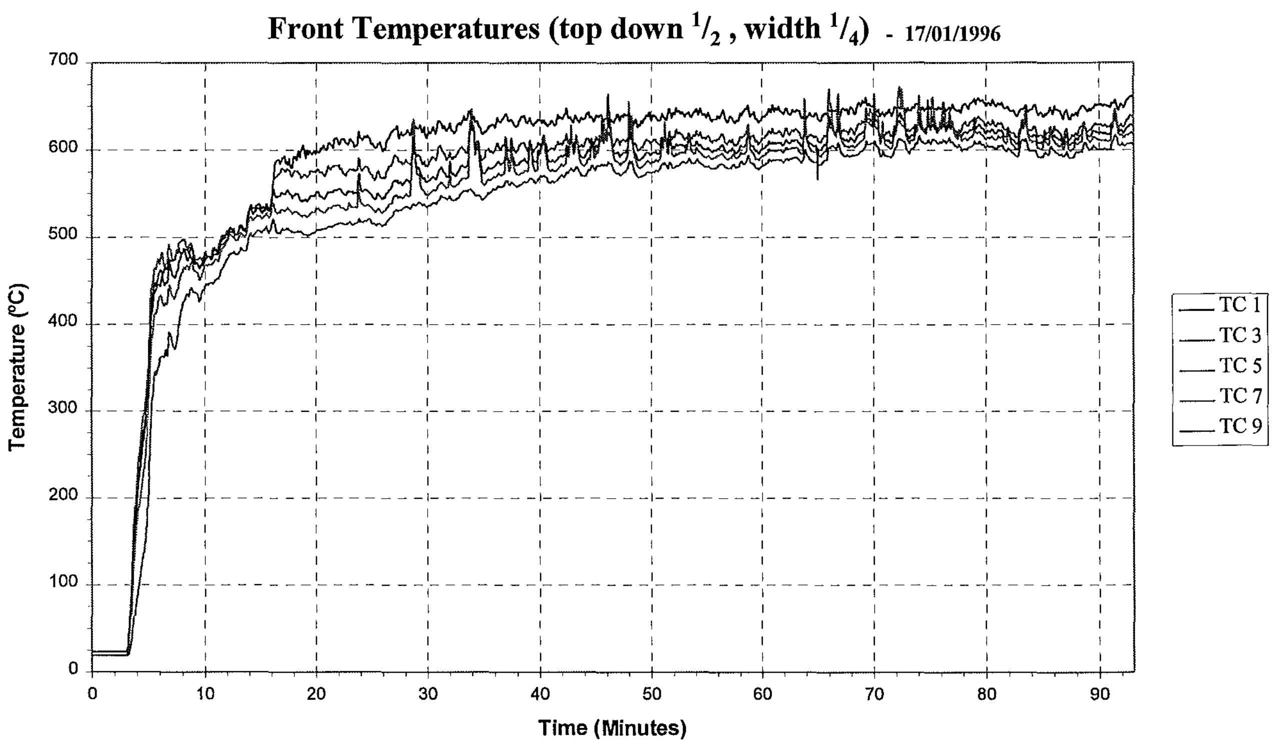
Weather Conditions: Average wind speed = 1.3 m/s
Maximum wind speed = 2.3 m/s

Comments:

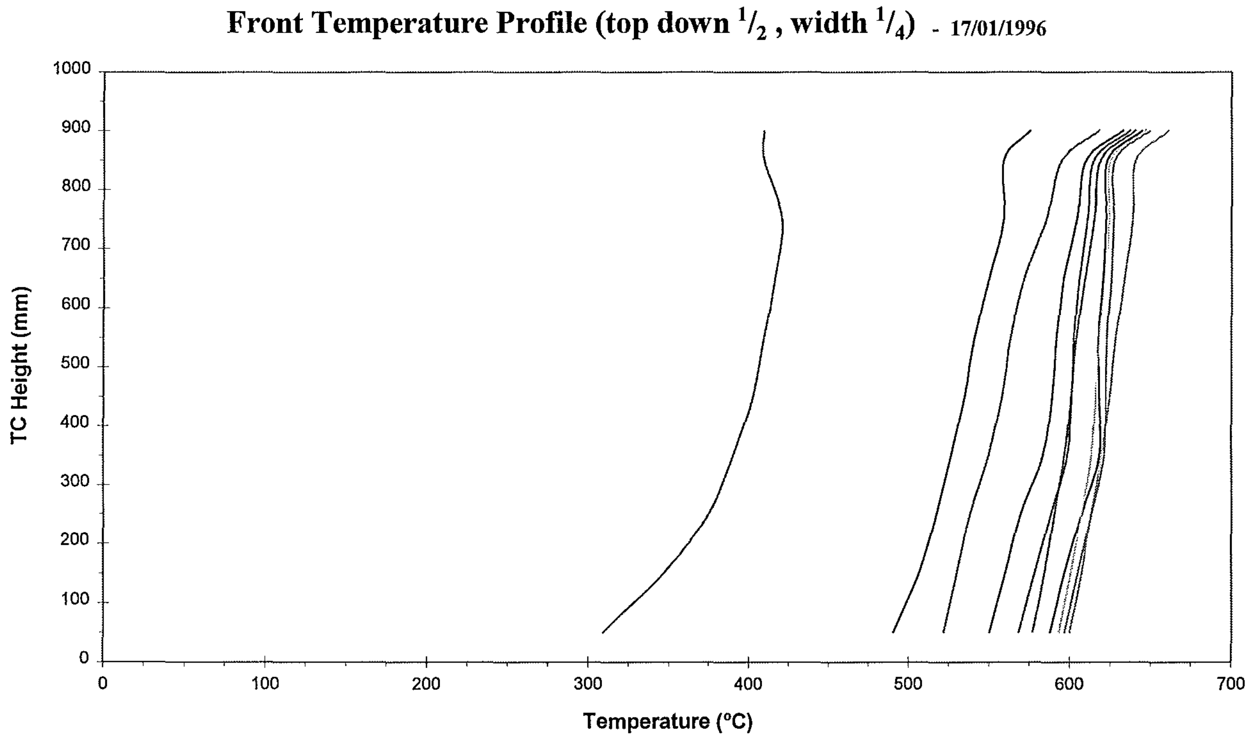


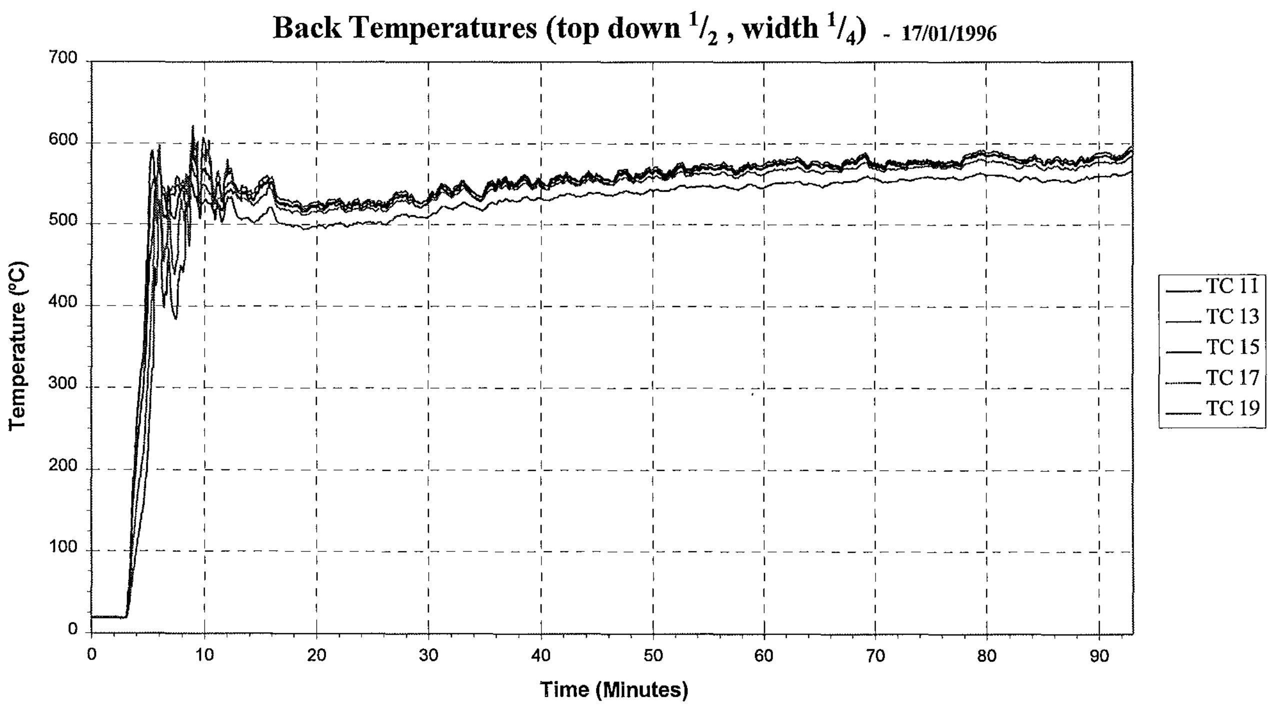


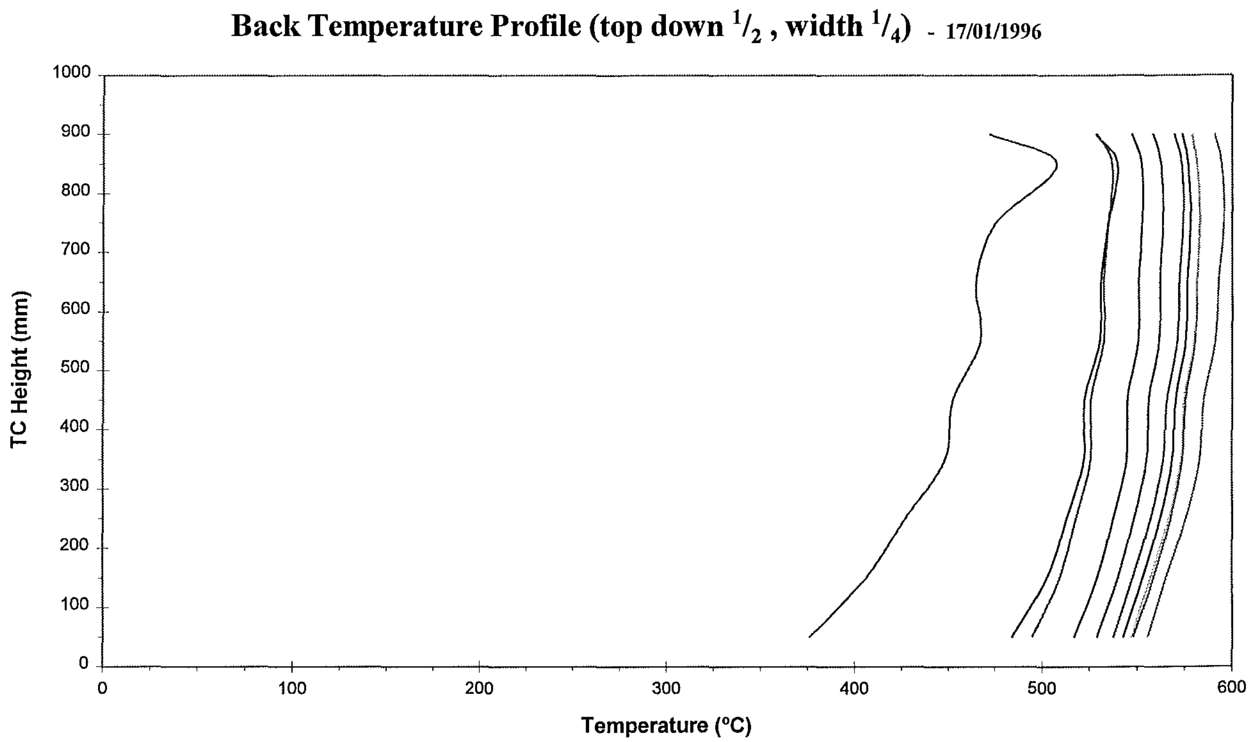
Mass Loss Rate (top down $^1/_2$, width $^1/_4$) - 17/01/1996
Mass Of Heptane (kg)
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
y = -0.0737x + 18.14
R^2 = 0.9996
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Time (Minutes)

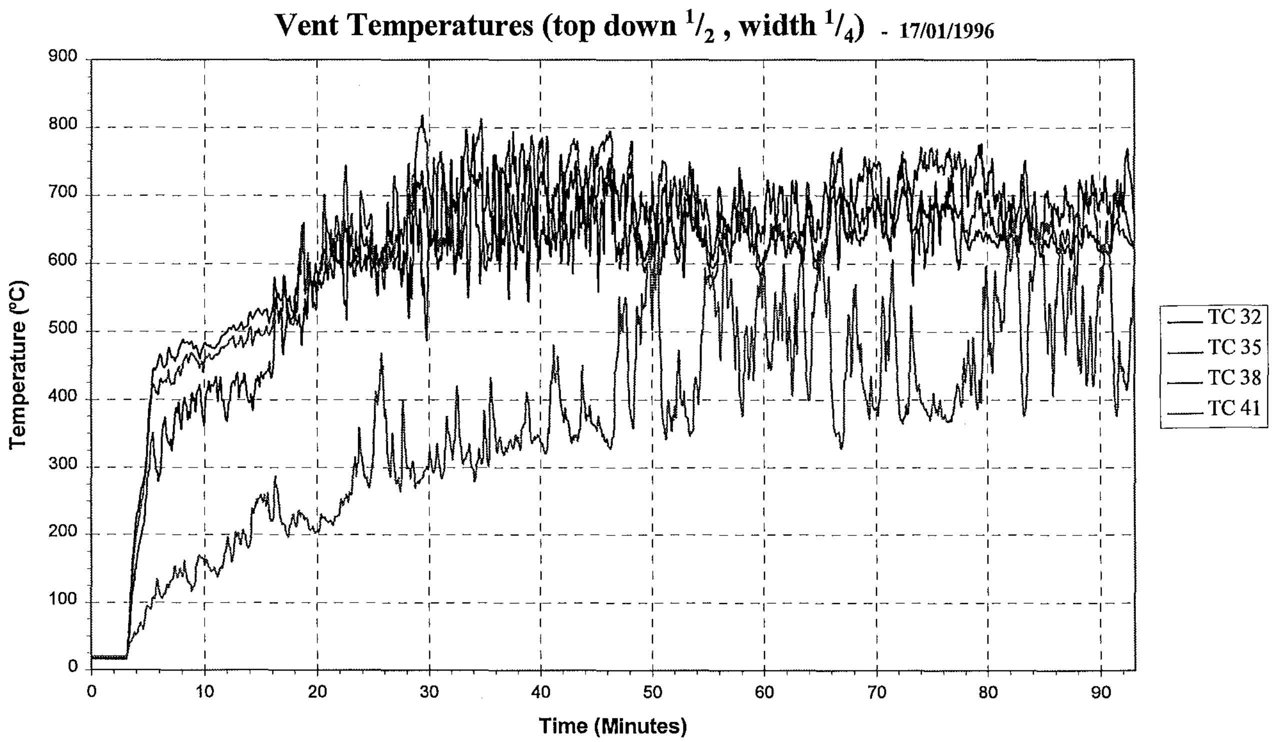


Front Temperatures (top down $^1/_2$, width $^1/_4$) - 17/01/1996
Temperature (ºC)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 1
TC 3
TC 5
TC 7
TC 9

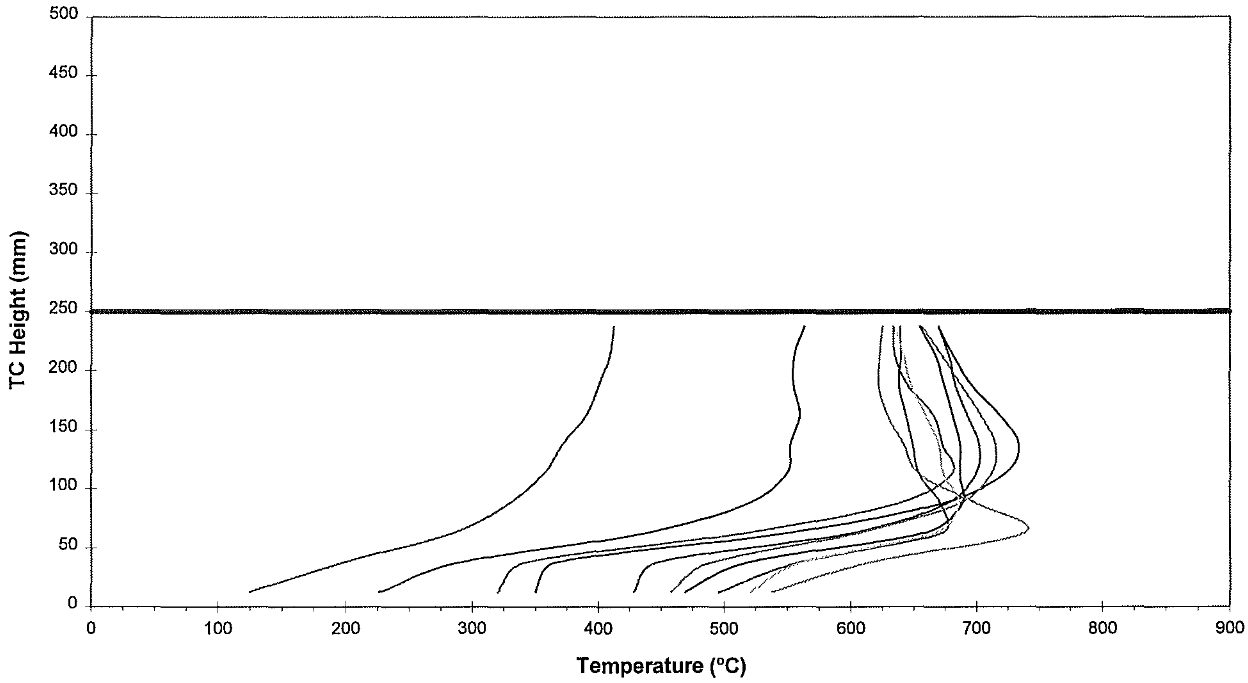

Front Temperature Profile (top down 1/2 , width 1/4) - 17/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000


Back Temperatures (top down 1/2 , width 1/4) - 17/01/1996
Temperature (°C)
Time (Minutes)
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
TC 11
TC 13
TC 15
TC 17
TC 19

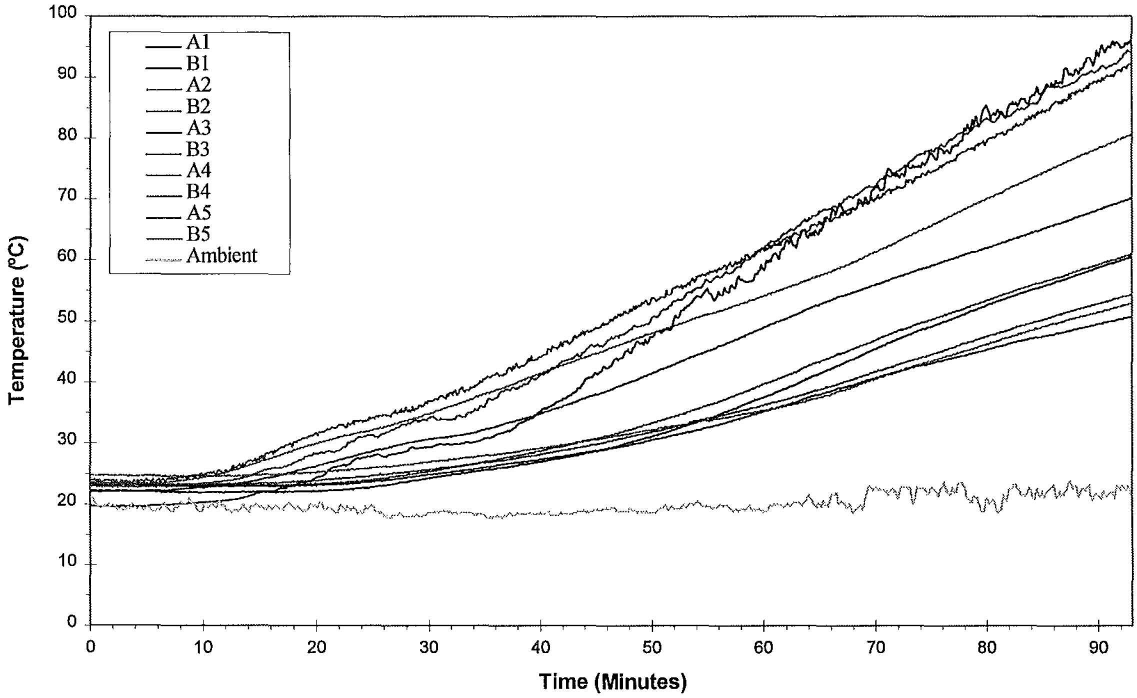

Back Temperature Profile (top down 1/2 , width 1/4) - 17/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
Temperature (°C)


Vent Temperatures (top down 1/2 , width 1/4) - 17/01/1996
Temperature (°C)
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 32
TC 35
TC 38
TC 41

Vent Temperature Profile (top down 1/2, width 1/4) - 17/01/1996



Wall Temperatures (top down 1/2, width 1/4) - 17/01/1996



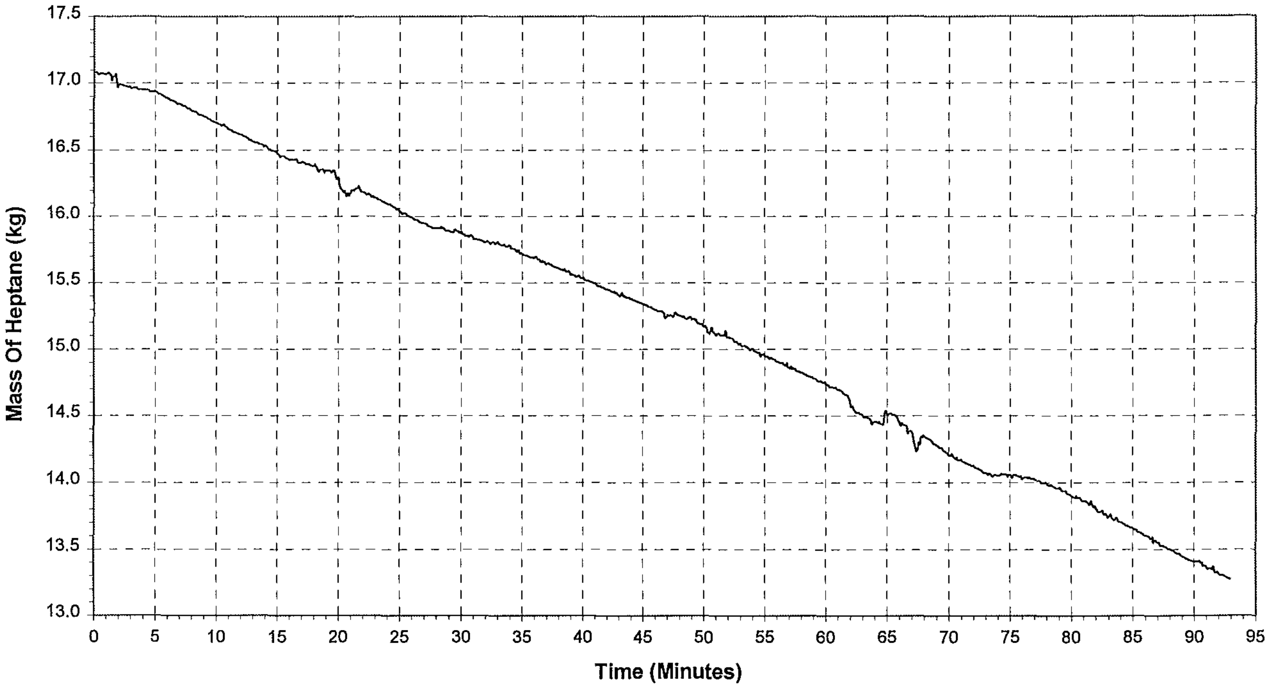
Test #8

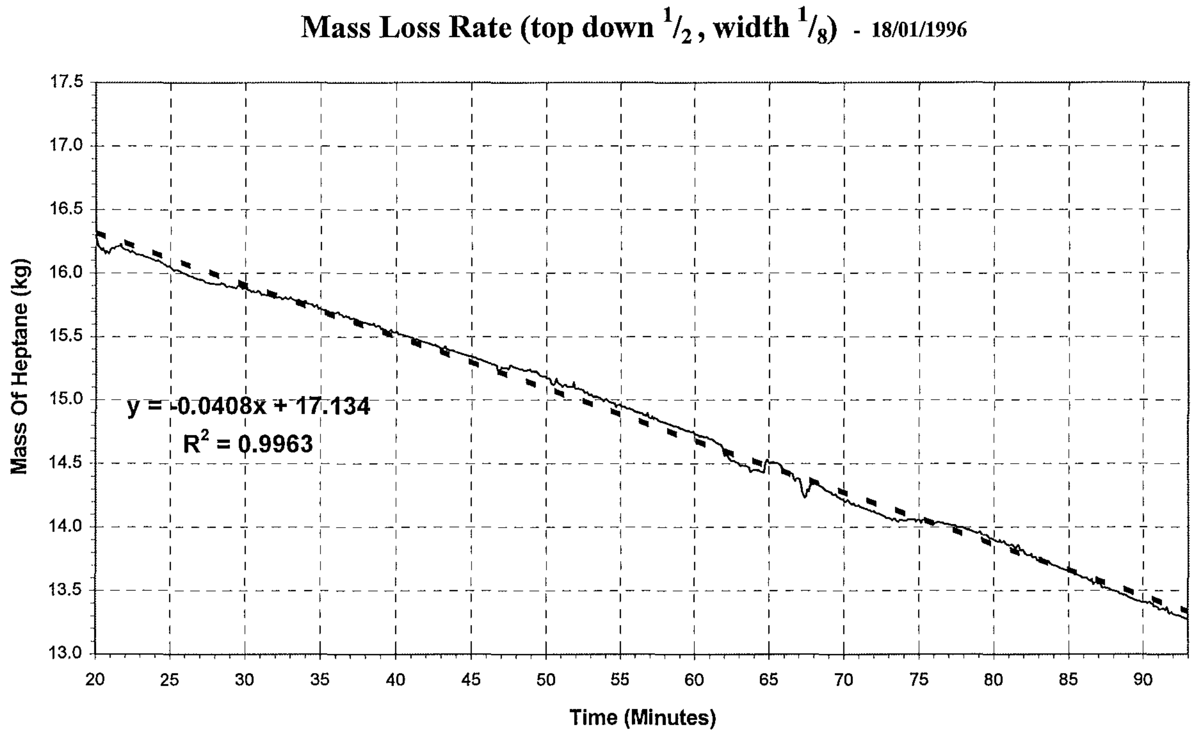
Ventilation Opening: Height - Top down $^1/_2$
Width - $^1/_8$

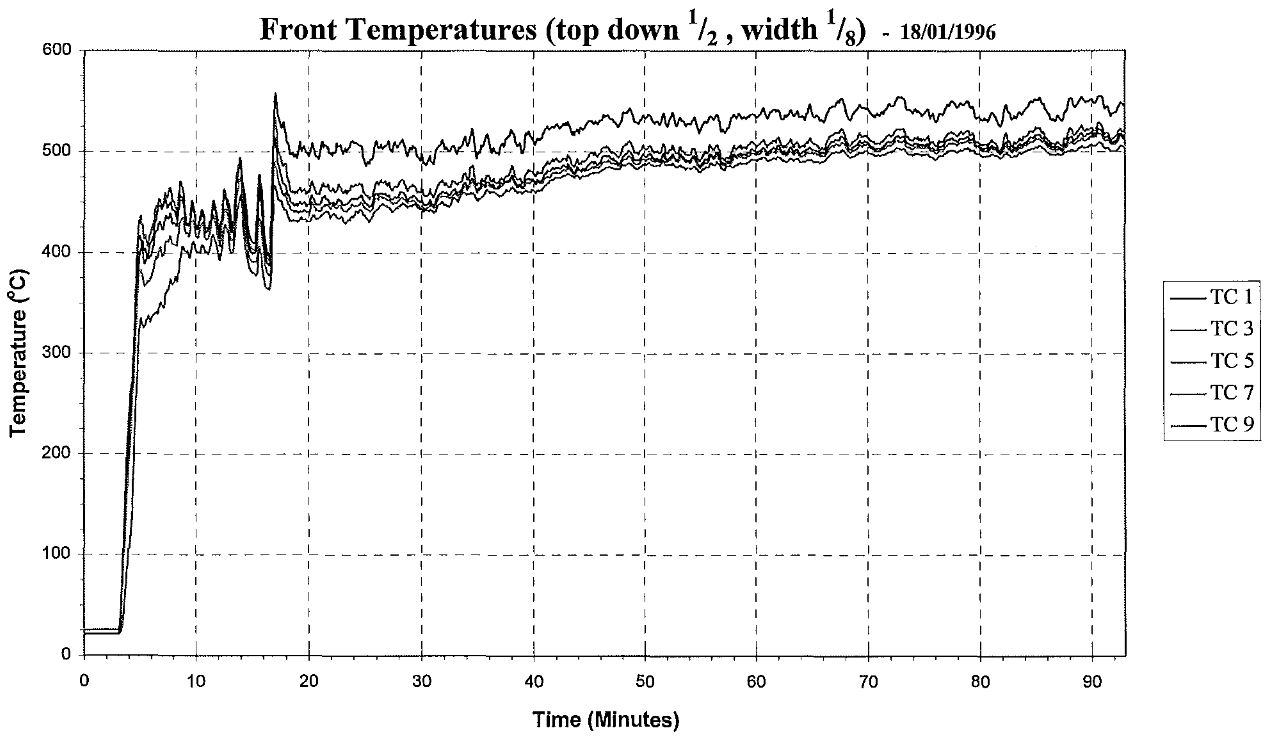
Weather Conditions: Average wind speed = 1.5 m/s
Maximum wind speed = 3.9 m/s

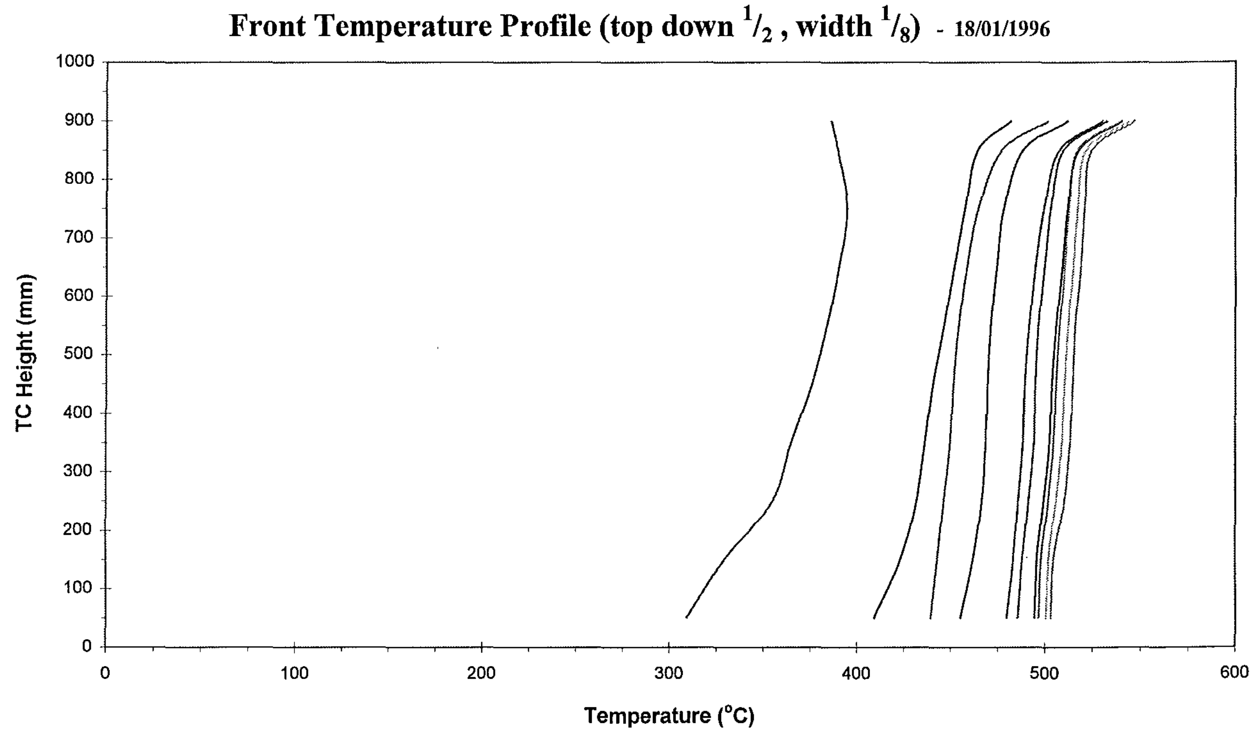
Comments:

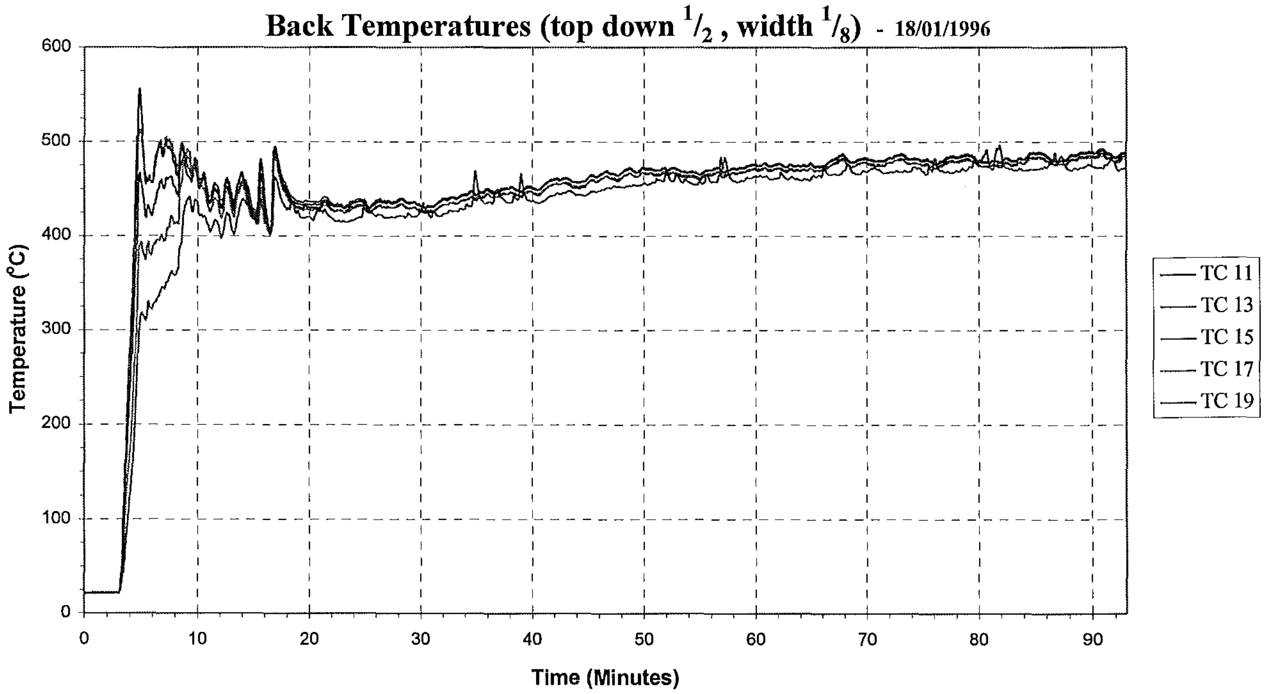
Heptane Mass Loss (top down $^1/_2$, width $^1/_8$) - **18/01/1996**

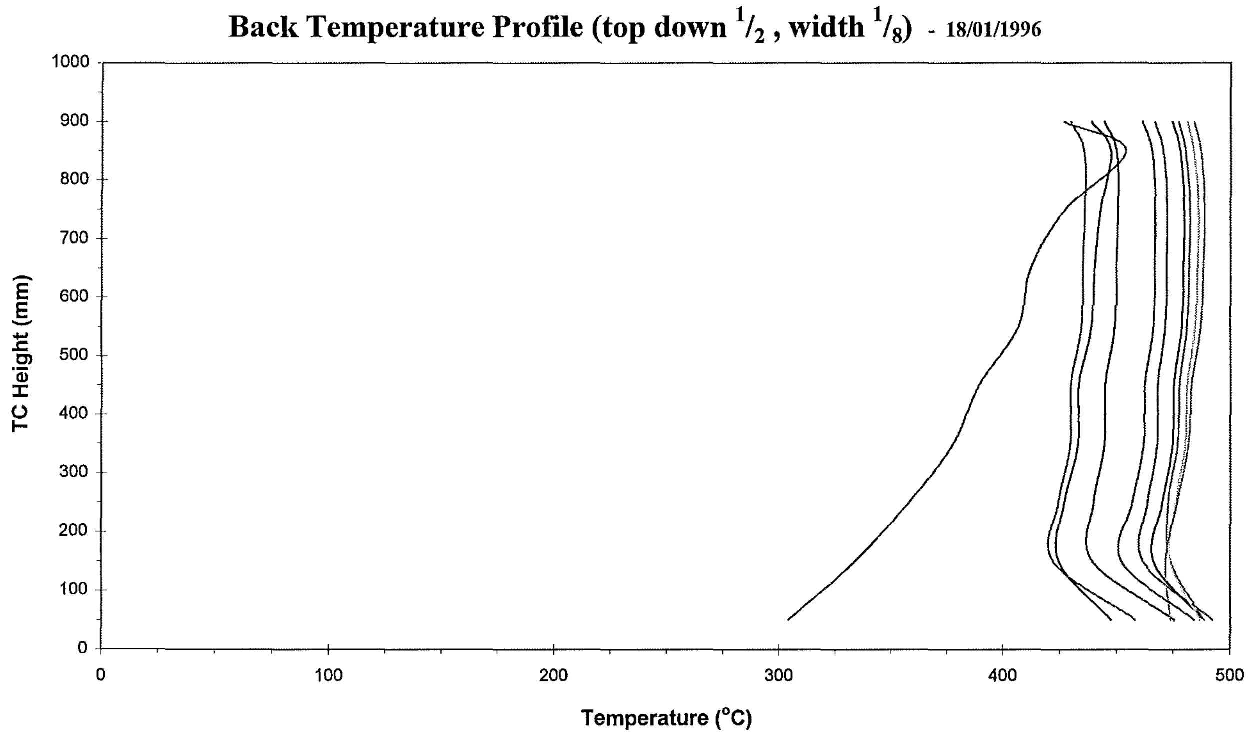


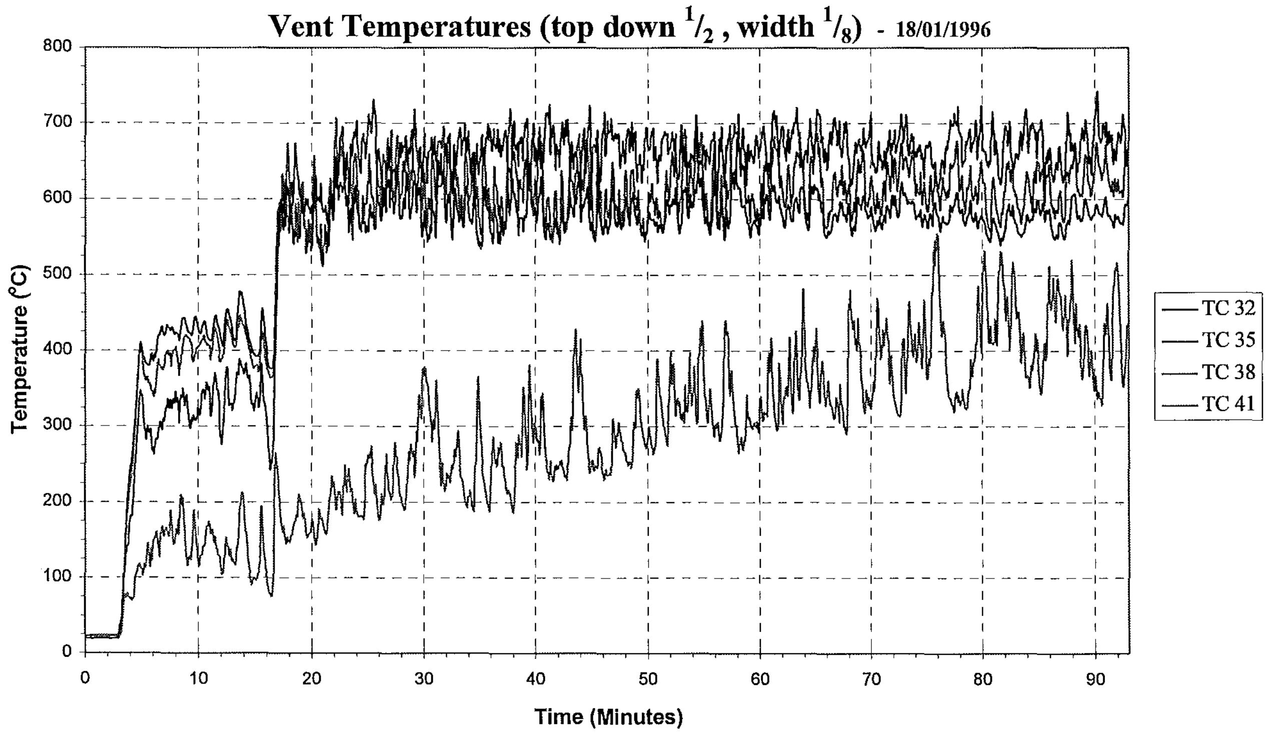

Mass Loss Rate (top down 1/2, width 1/8) - 18/01/1996
y = -0.0408x + 17.134
R2 = 0.9963
Mass Of Heptane (kg)
Time (Minutes)
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

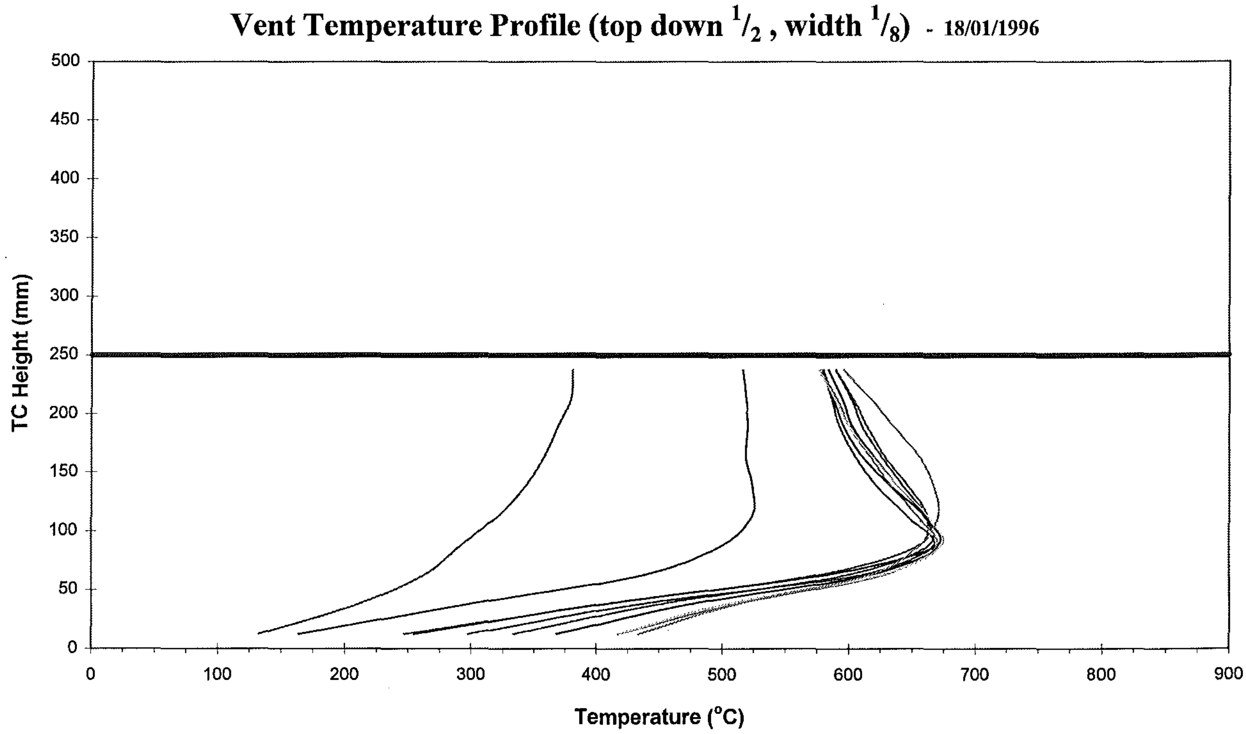

Front Temperatures (top down 1/2, width 1/8) - 18/01/1996
Temperature (°C)
Time (Minutes)
TC 1
TC 3
TC 5
TC 7
TC 9
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90

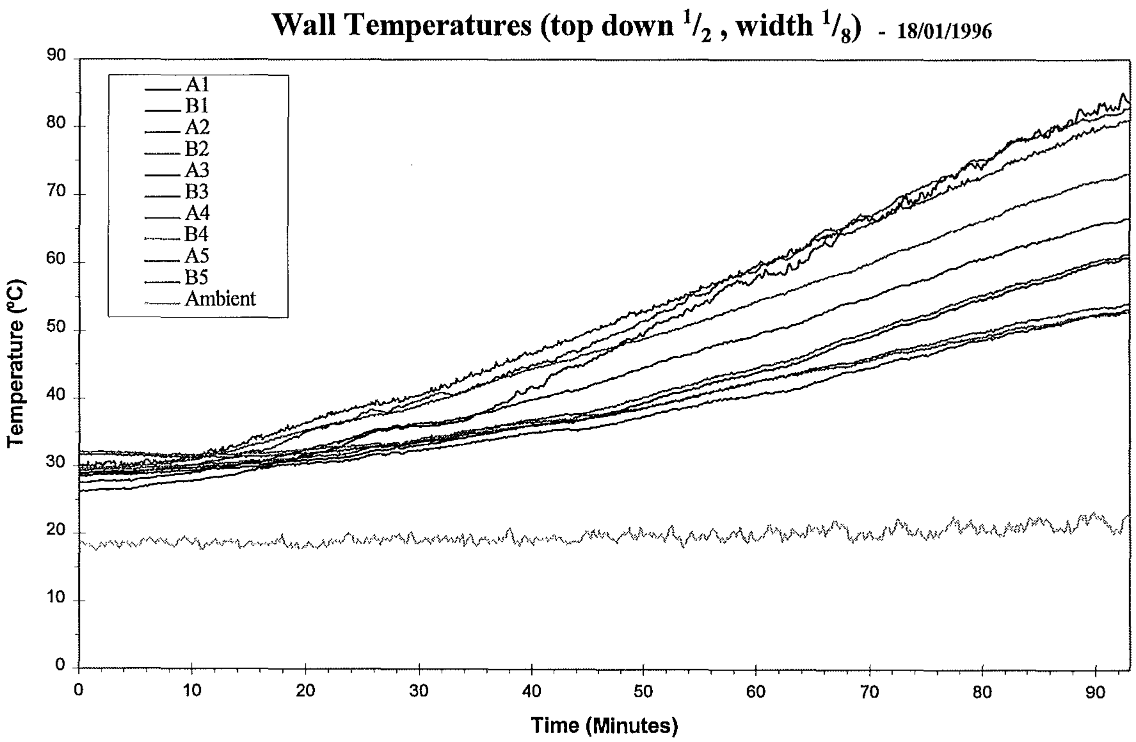

Front Temperature Profile (top down $^1/_2$, width $^1/_8$) - 18/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000


Back Temperatures (top down $^1/_2$, width $^1/_8$) - 18/01/1996
Temperature (°C)
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19


Back Temperature Profile (top down $^1/_2$, width $^1/_8$) - 18/01/1996
TC Height (mm)
Temperature (°C)


Vent Temperatures (top down $^1/_2$, width $^1/_8$) - 18/01/1996
Temperature (°C)
Time (Minutes)
TC 32
TC 35
TC 38
TC 41


Vent Temperature Profile (top down 1/2 , width 1/8) - 18/01/1996
TC Height (mm)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Temperature (°C)


Wall Temperatures (top down 1/2 , width 1/8) - 18/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)

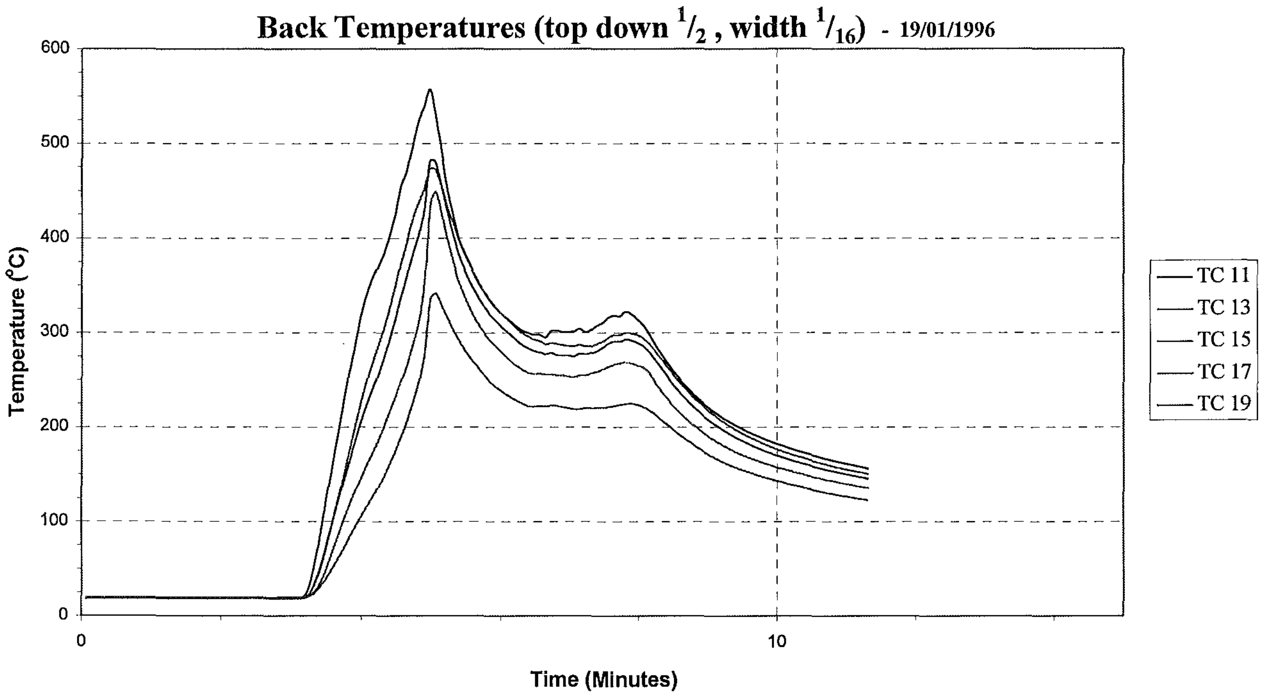
TESTS #9 AND #10

Ventilation Opening: Height - Top down $^1/_2$
Width - $^1/_{16}$

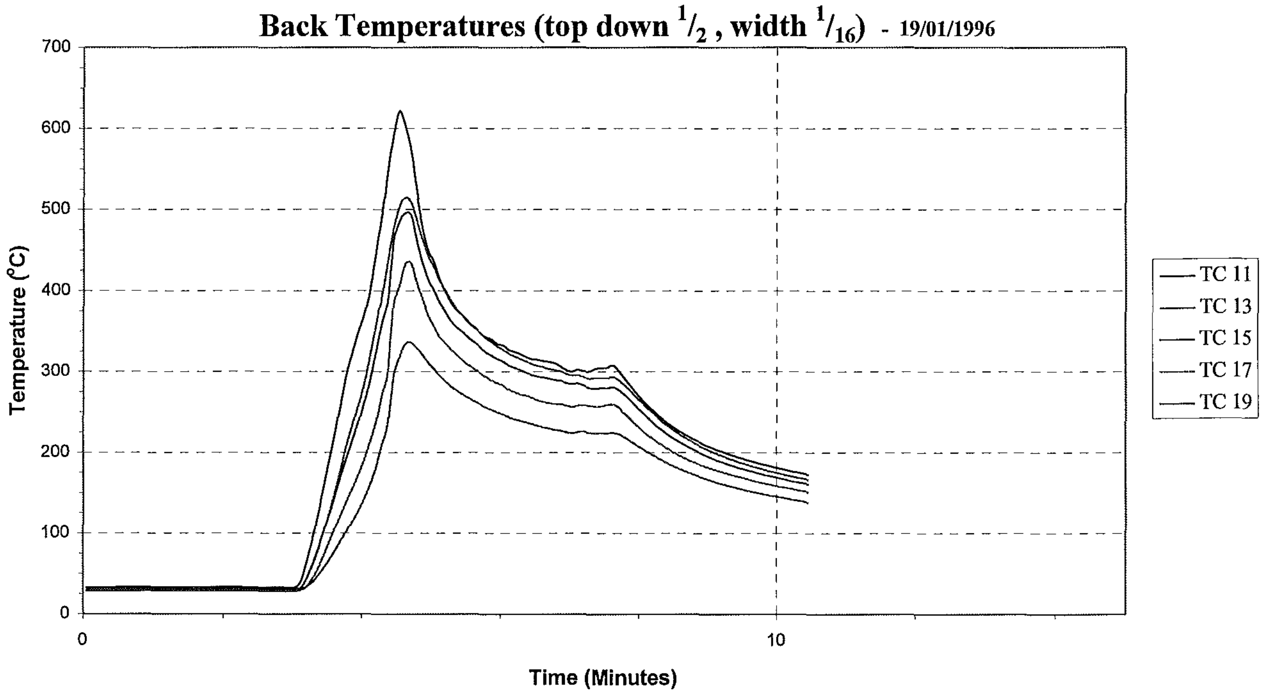
Weather Conditions: Average wind speed = 1.0 m/s
Maximum wind speed = 2.1 m/s

Comments: Both fires self extinguished.

- Test #9



- Test #10


Back Temperatures (top down 1/2 , width 1/16) - 19/01/1996
700
600
500
400
300
200
100
0
Temperature (°C)
0
10
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19

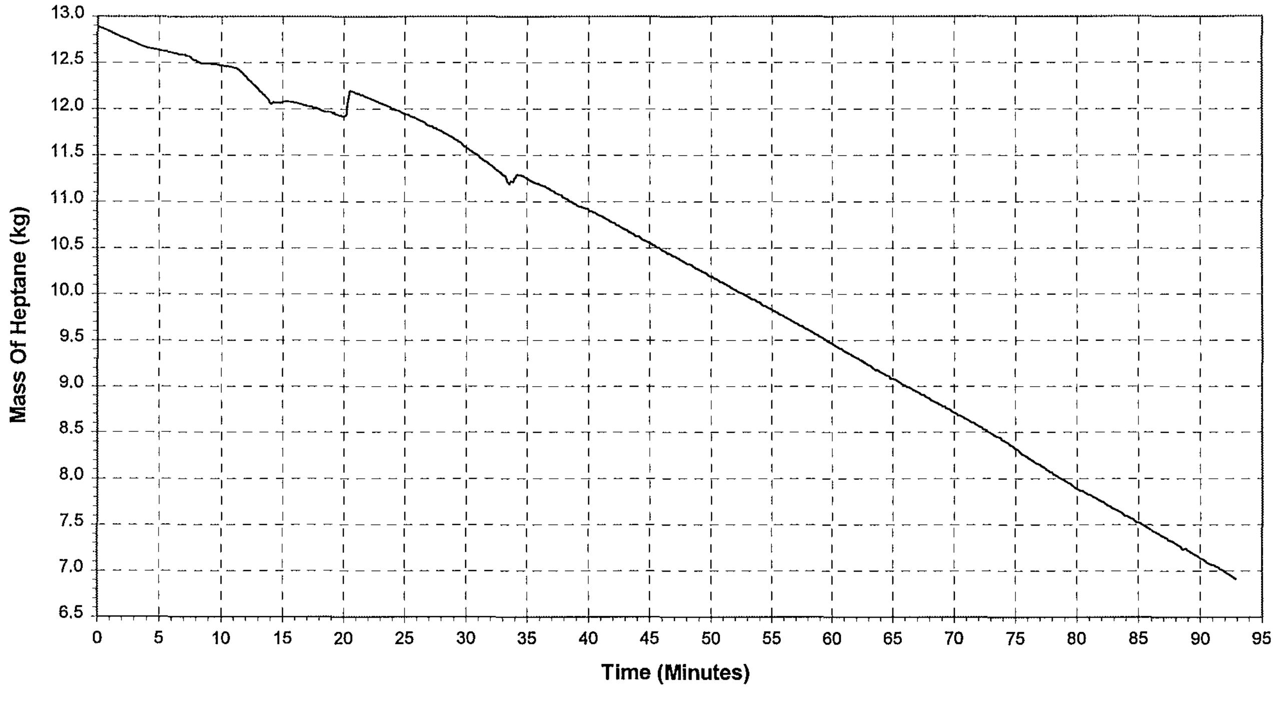
TEST #11

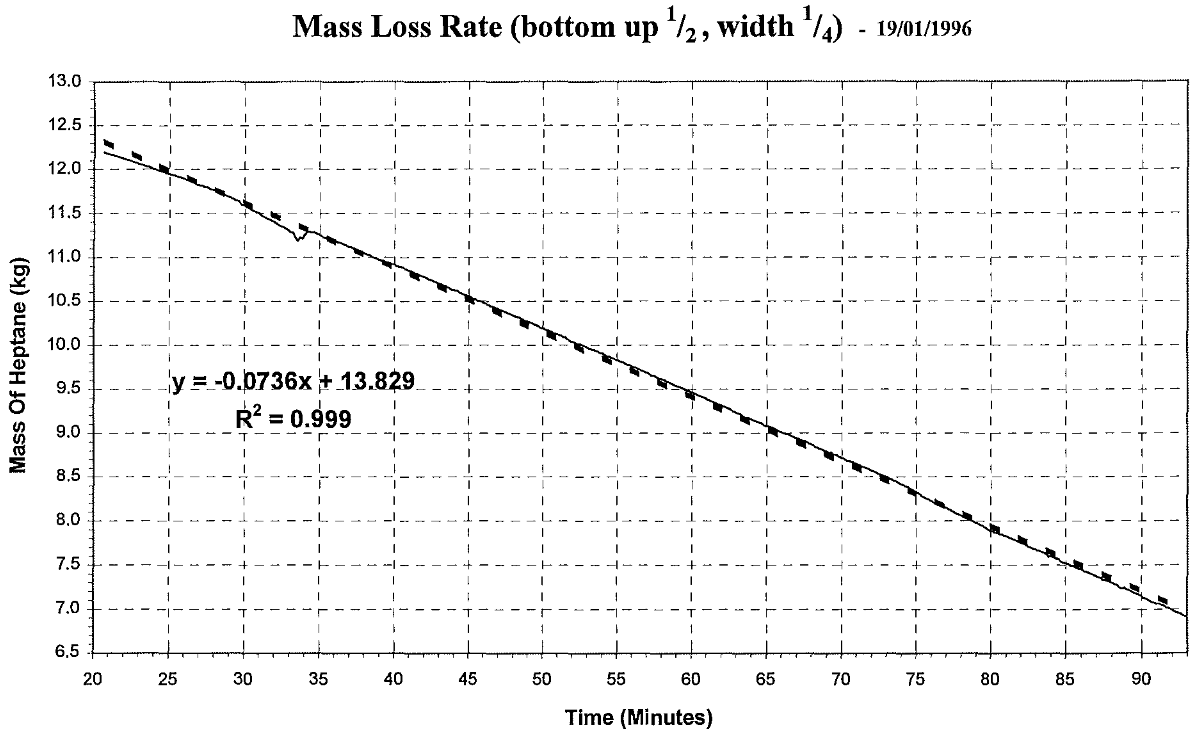
Ventilation Opening: Height - Bottom up $^1/_2$
Width - $^1/_4$

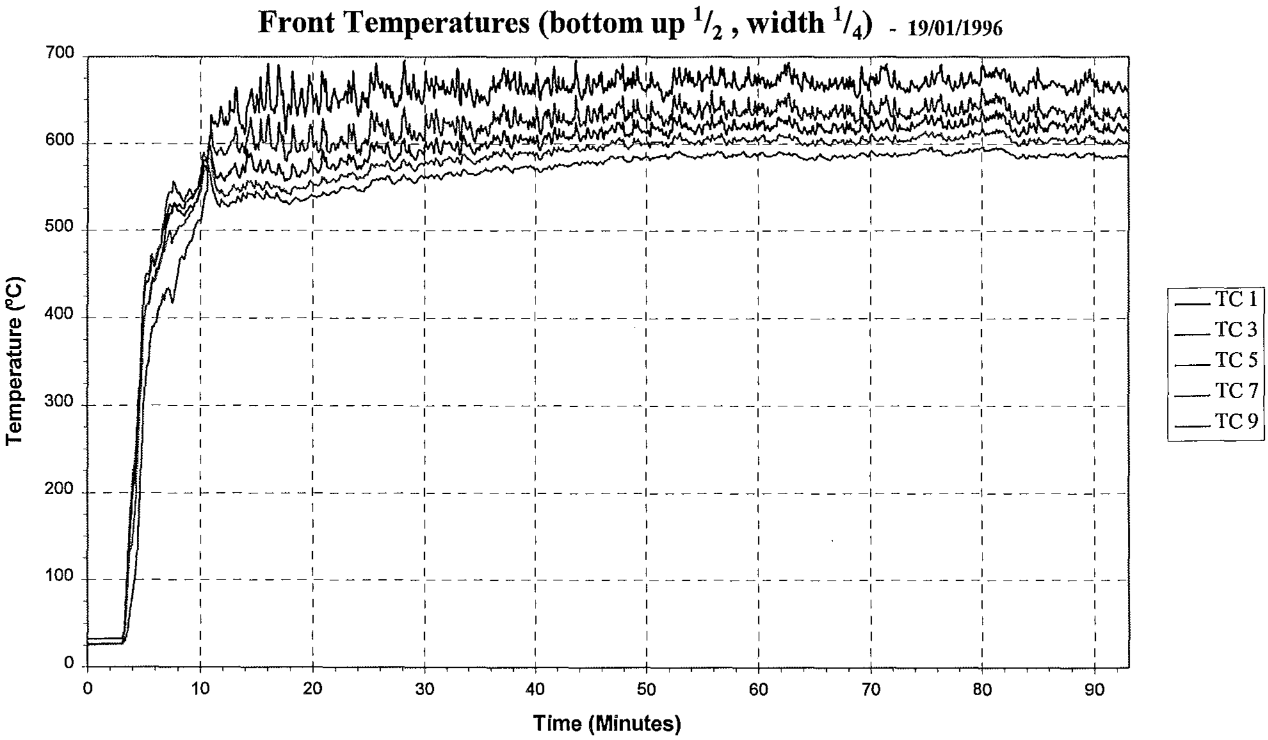
Weather Conditions: Average wind speed = 1.0 m/s
Maximum wind speed = 2.7 m/s

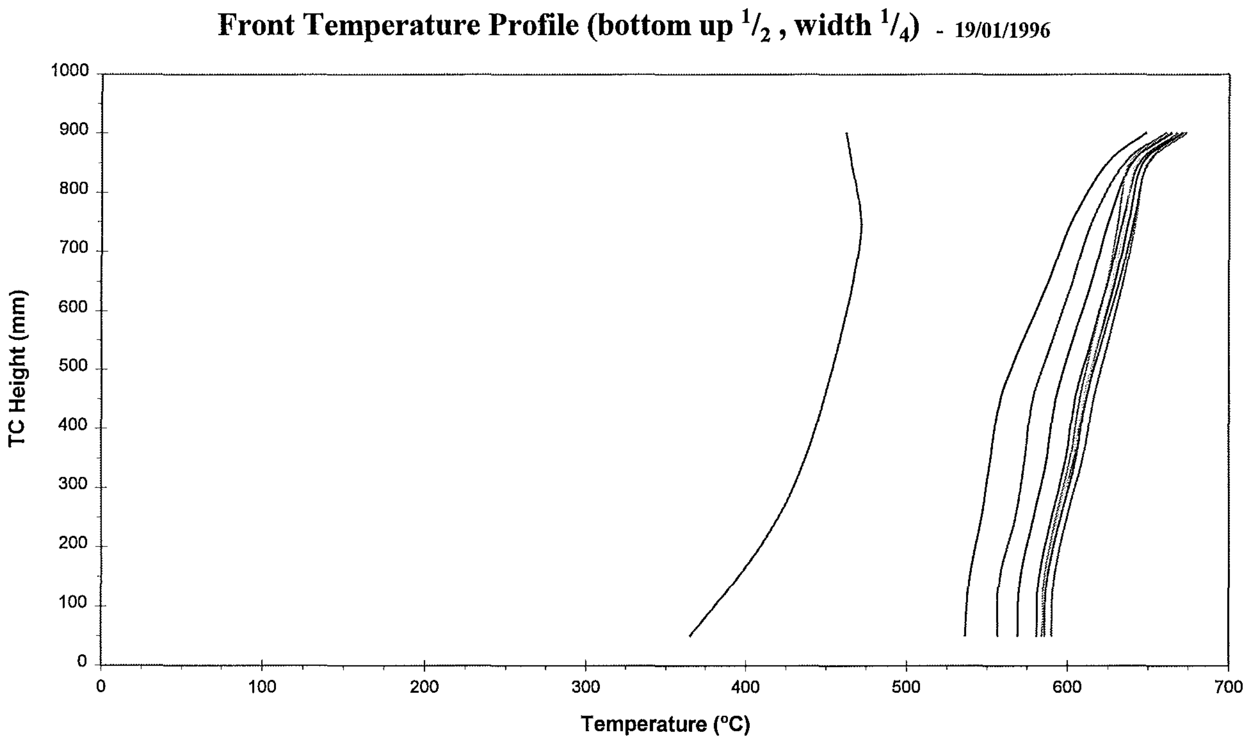
Comments:

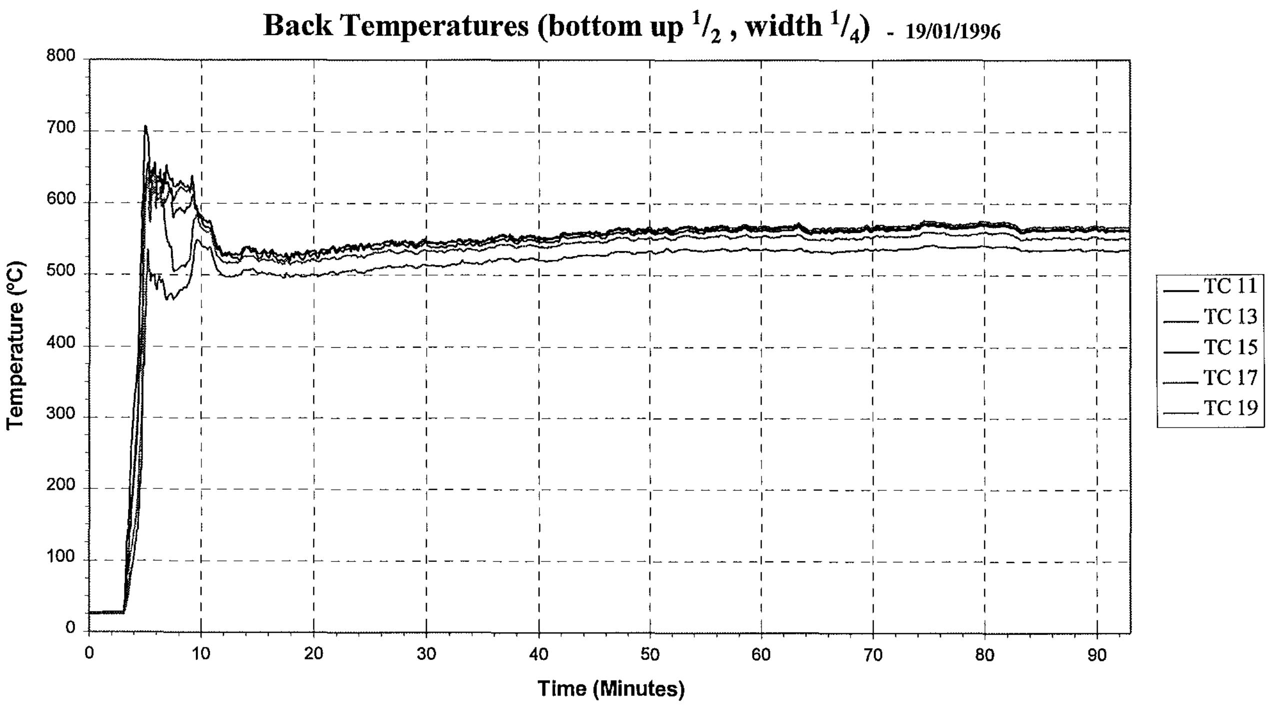
Heptane Mass Loss (bottom up $^1/_2$, width $^1/_4$) - 19/01/1996

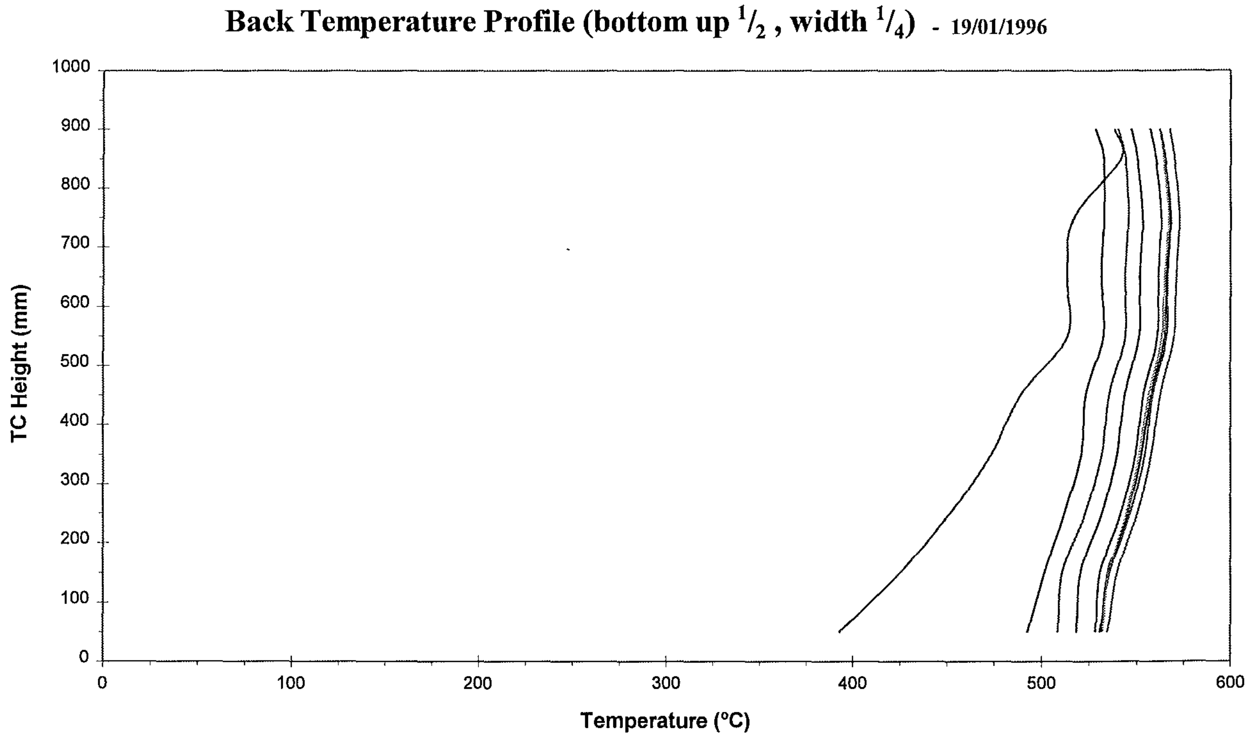



Mass Loss Rate (bottom up 1/2, width 1/4) - 19/01/1996
y = -0.0736x + 13.829
R² = 0.999
Mass Of Heptane (kg)
Time (Minutes)
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

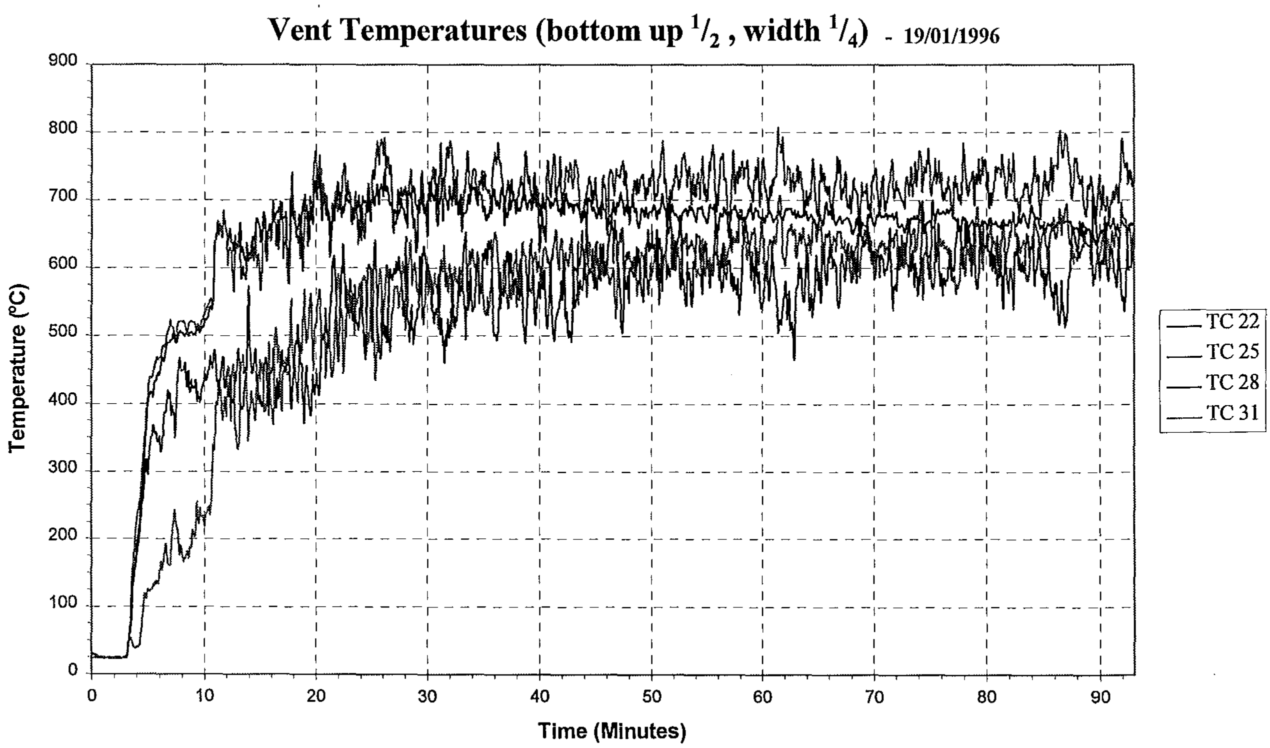

Front Temperatures (bottom up 1/2 , width 1/4) - 19/01/1996
Temperature (°C)
Time (Minutes)
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
TC 1
TC 3
TC 5
TC 7
TC 9


Front Temperature Profile (bottom up $^1/_2$, width $^1/_4$) - 19/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
Temperature (°C)


Back Temperatures (bottom up $^1/_2$, width $^1/_4$) - 19/01/1996
Temperature (°C)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19

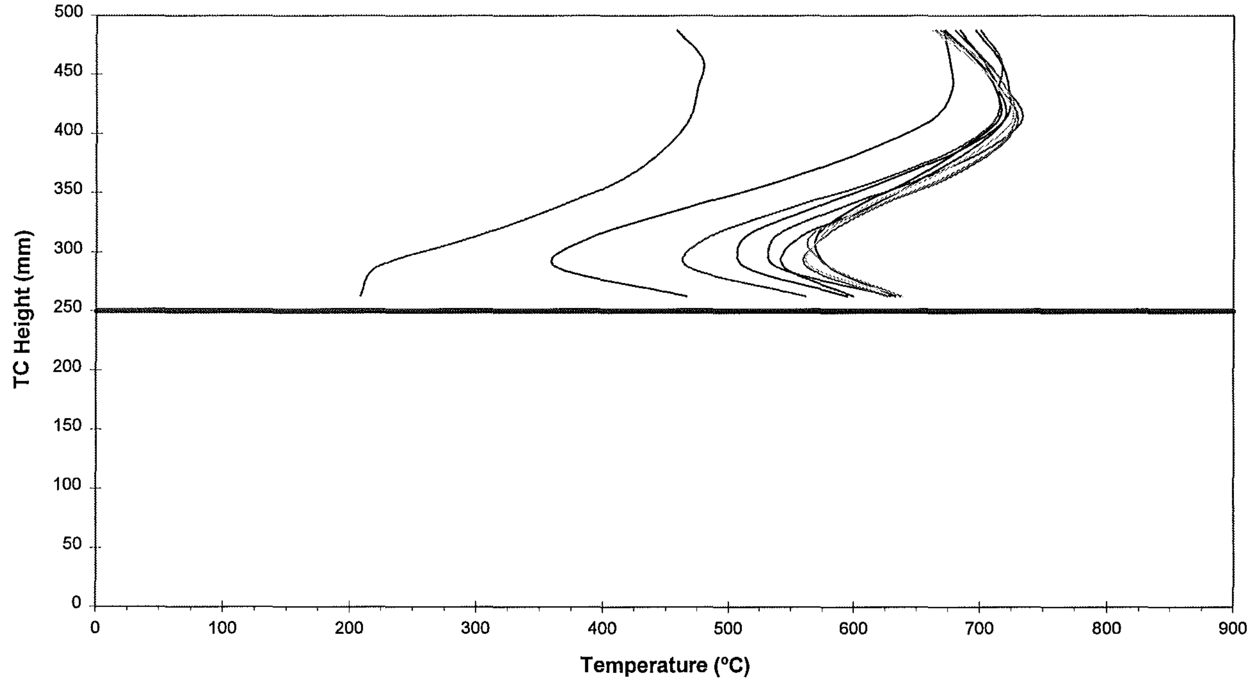


Back Temperature Profile (bottom up 1/2, width 1/4) - 19/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000

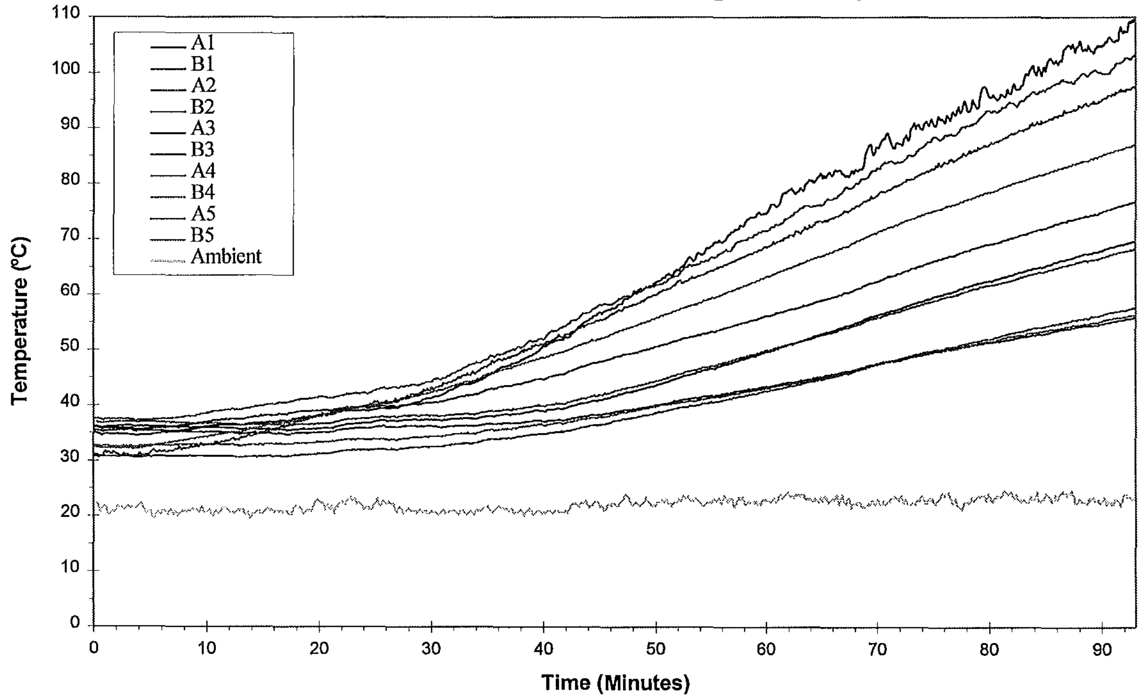


Vent Temperatures (bottom up 1/2, width 1/4) - 19/01/1996
Temperature (°C)
Time (Minutes)
TC 22
TC 25
TC 28
TC 31

Vent Temperature Profile (bottom up 1/2, width 1/4) - 19/01/1996



Wall Temperatures (bottom up 1/2, width 1/4) - 19/01/1996



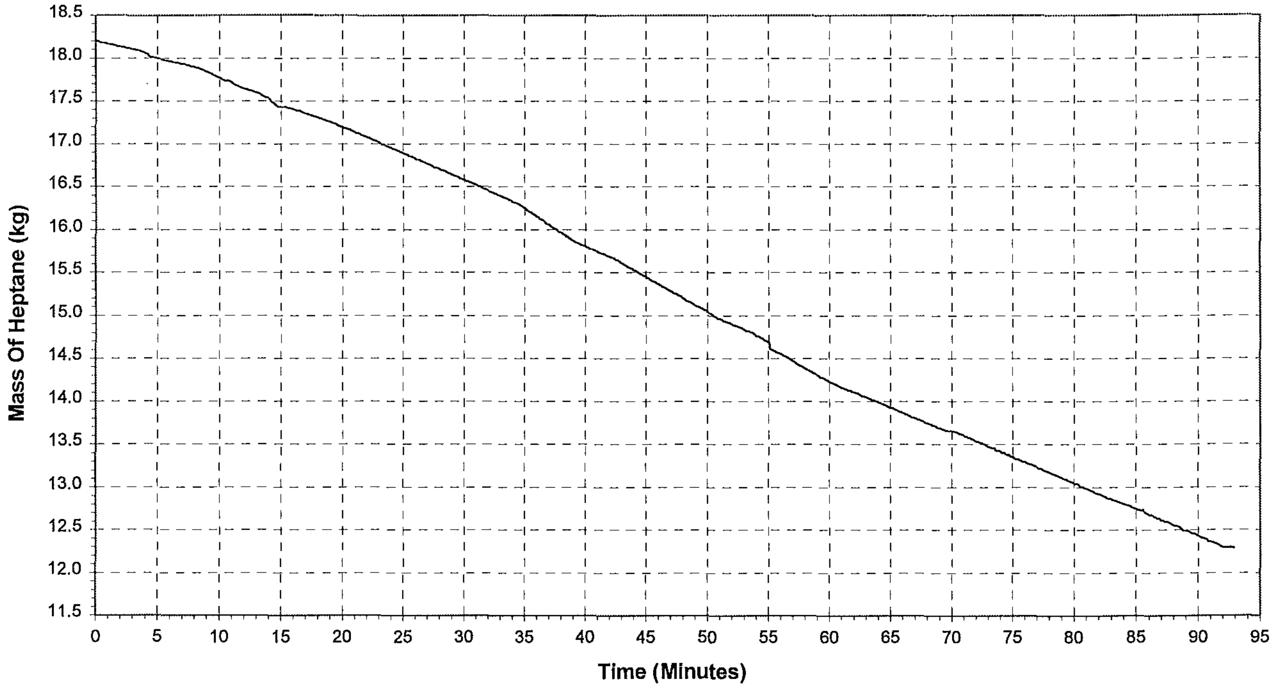
TEST #12

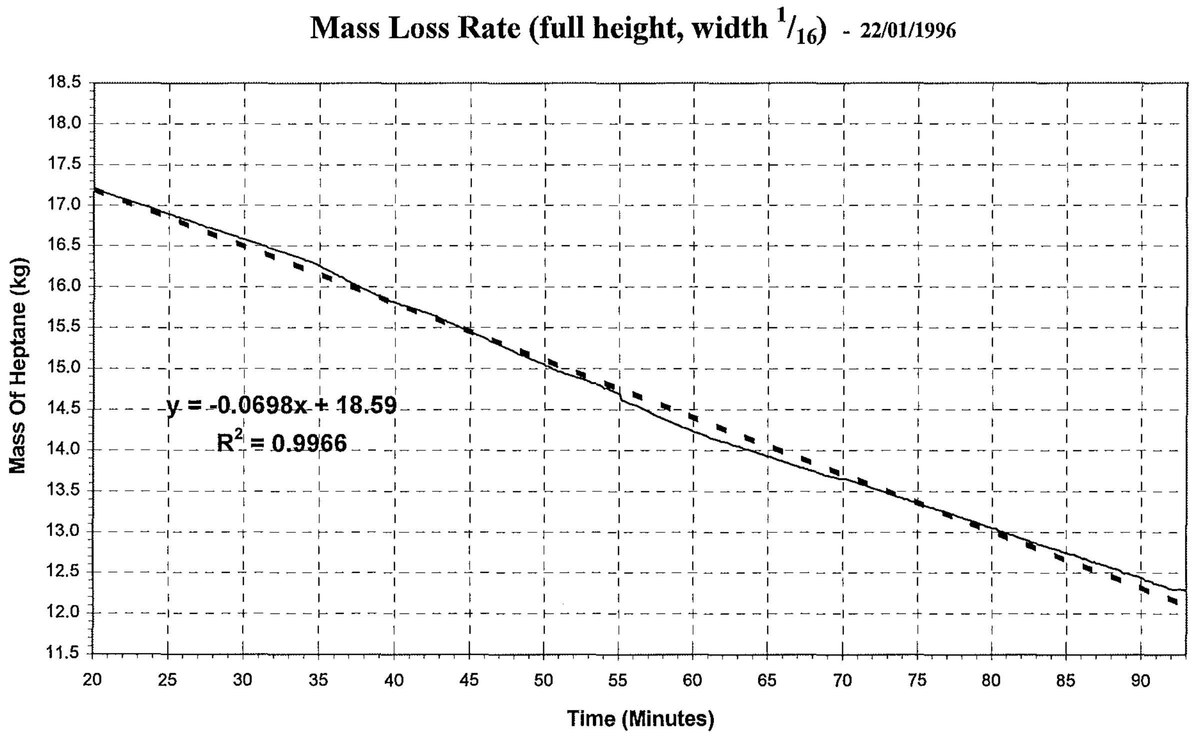
Ventilation Opening: Height - Full
Width - $^{1}/_{16}$

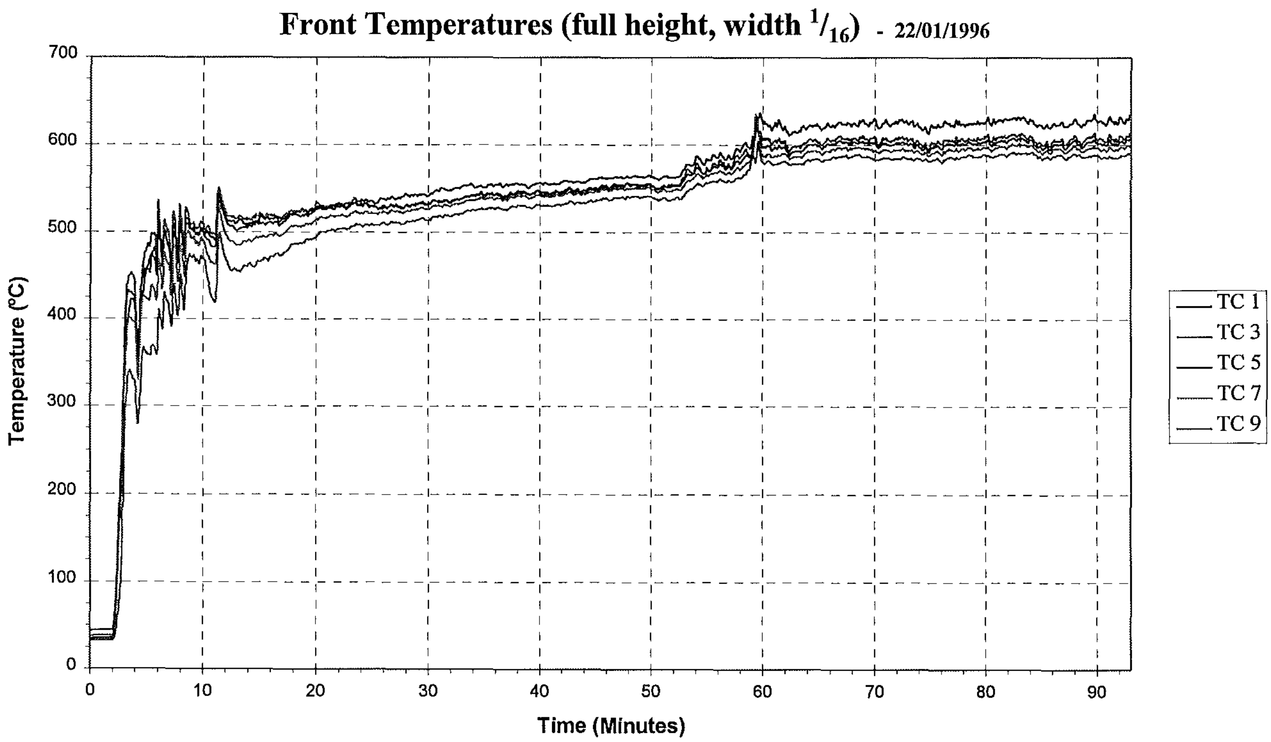
Weather Conditions: Average wind speed = 0.8 m/s
Maximum wind speed = 2.1 m/s

Comments: This experiment was conducted to run for 90 minutes instead of 65 minutes that occured in the first run.

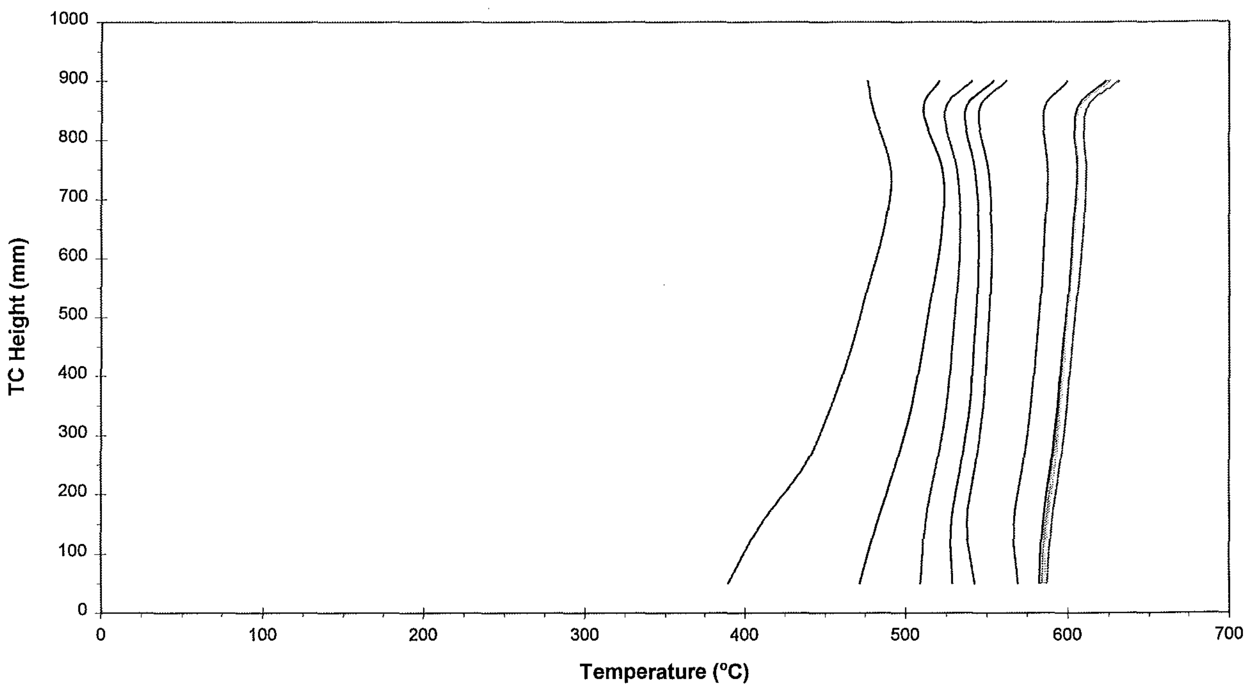
Heptane Mass Loss (full height, width $^{1}/_{16}$) - 22/01/1996



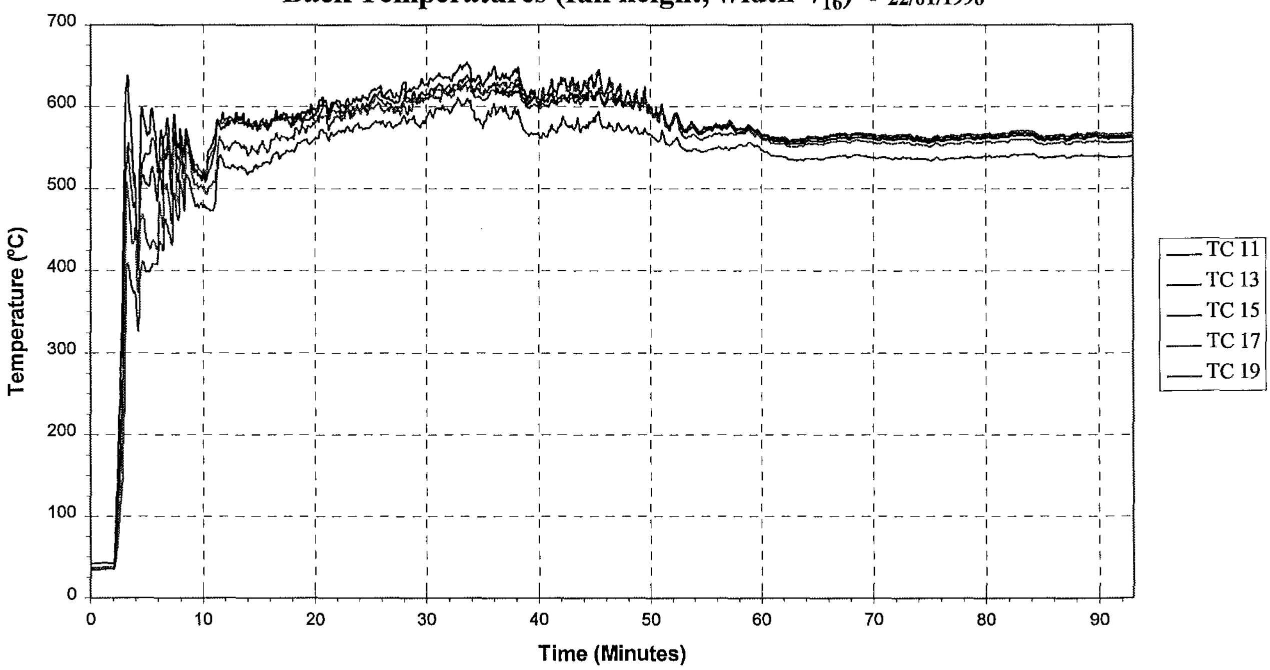

Mass Loss Rate (full height, width 1/16) - 22/01/1996
y = -0.0698x + 18.59
R2 = 0.9966
Mass Of Heptane (kg)
Time (Minutes)
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

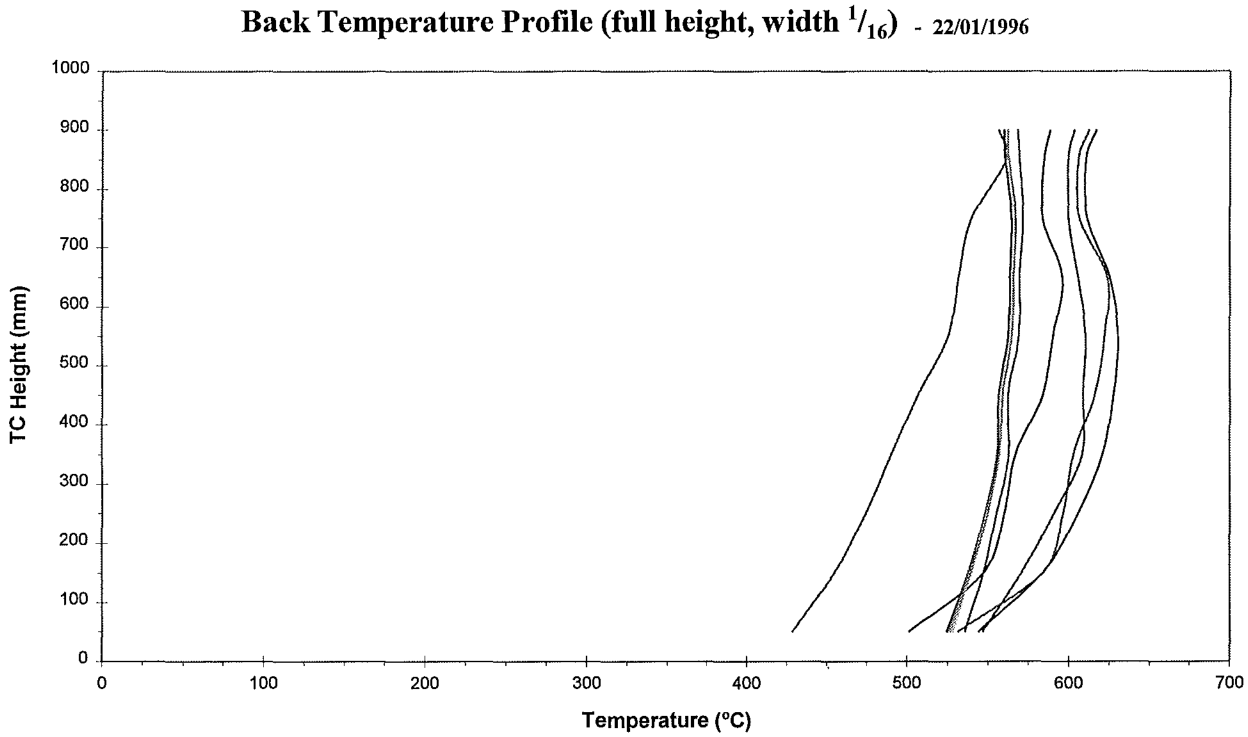

Front Temperatures (full height, width 1/16) - 22/01/1996
Temperature (°C)
Time (Minutes)
TC 1
TC 3
TC 5
TC 7
TC 9
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90

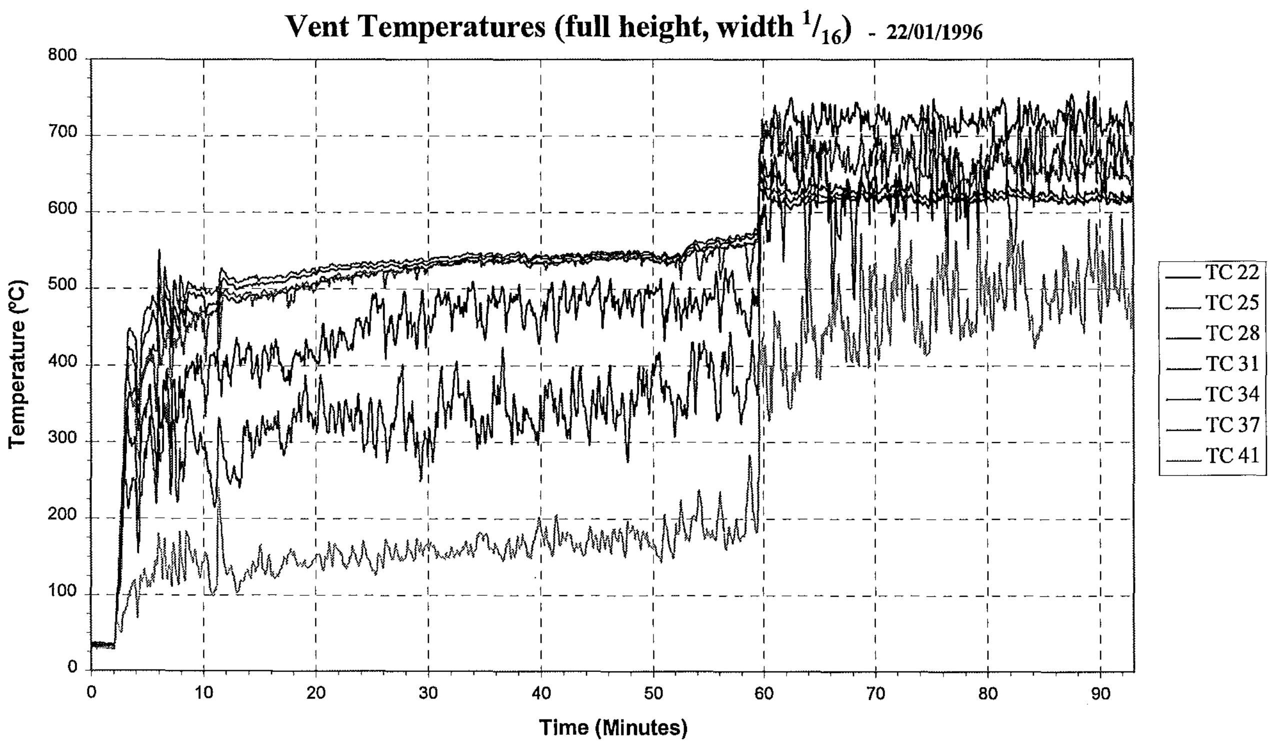
Front Temperature Profile (full height, width $^1/_{16}$) - 22/01/1996

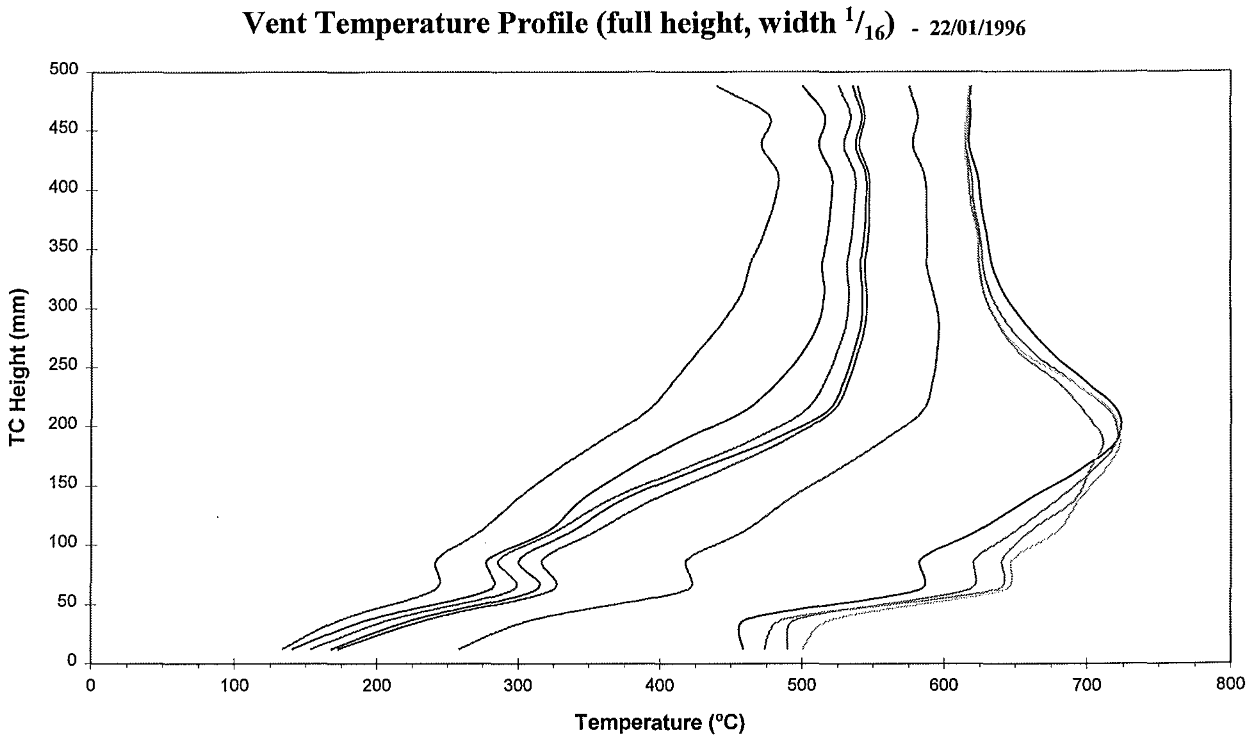


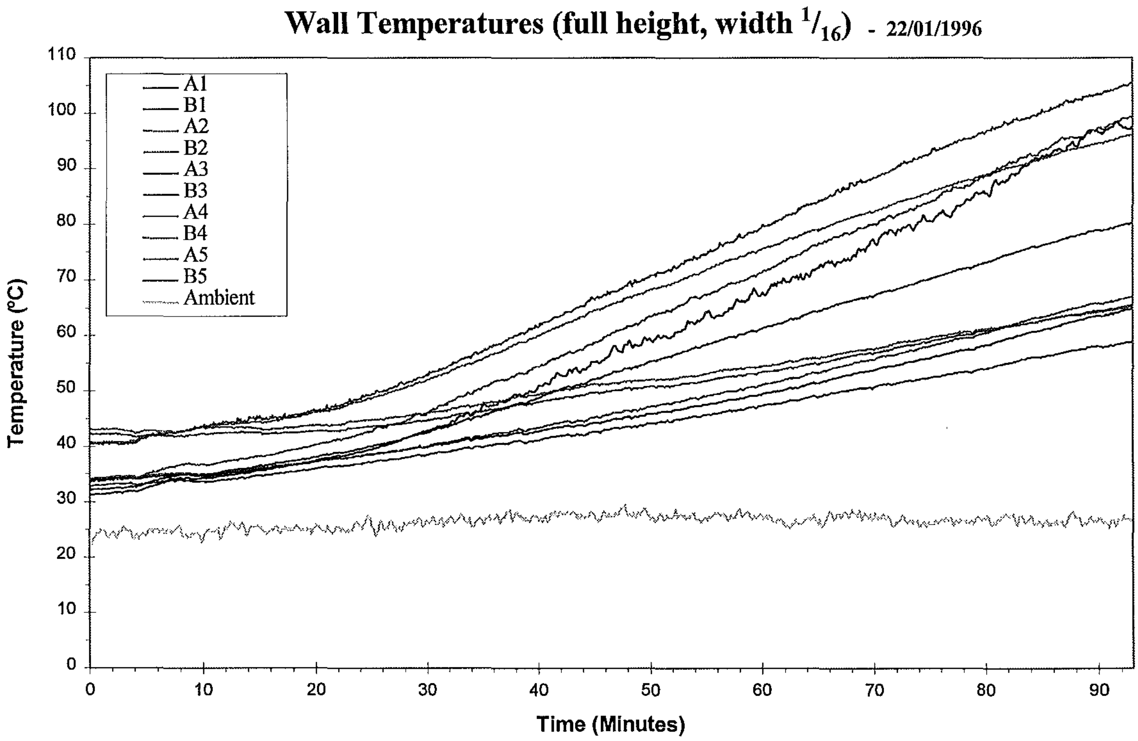
Back Temperatures (full height, width $^1/_{16}$) - 22/01/1996




Back Temperature Profile (full height, width $^1/_{16}$) - 22/01/1996
1000
900
800
700
600
500
400
300
200
100
0
TC Height (mm)
0
100
200
300
400
500
600
700
Temperature (°C)


Vent Temperatures (full height, width $^1/_{16}$) - 22/01/1996
800
700
600
500
400
300
200
100
0
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41


Vent Temperature Profile (full height, width 1/16) - 22/01/1996
TC Height (mm)
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800


Wall Temperatures (full height, width 1/16) - 22/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
Temperature (°C)
Time (Minutes)
0
10
20
30
40
50
60
70
80
90
100
110

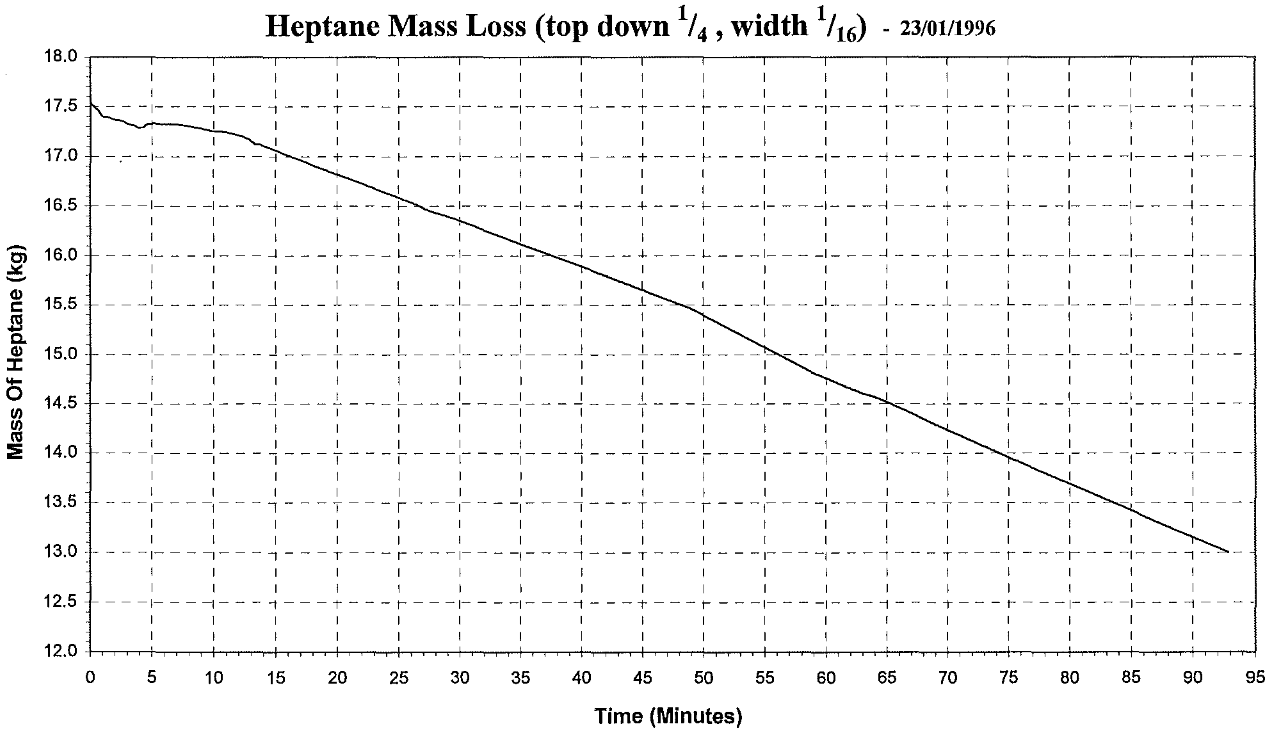
TEST #13

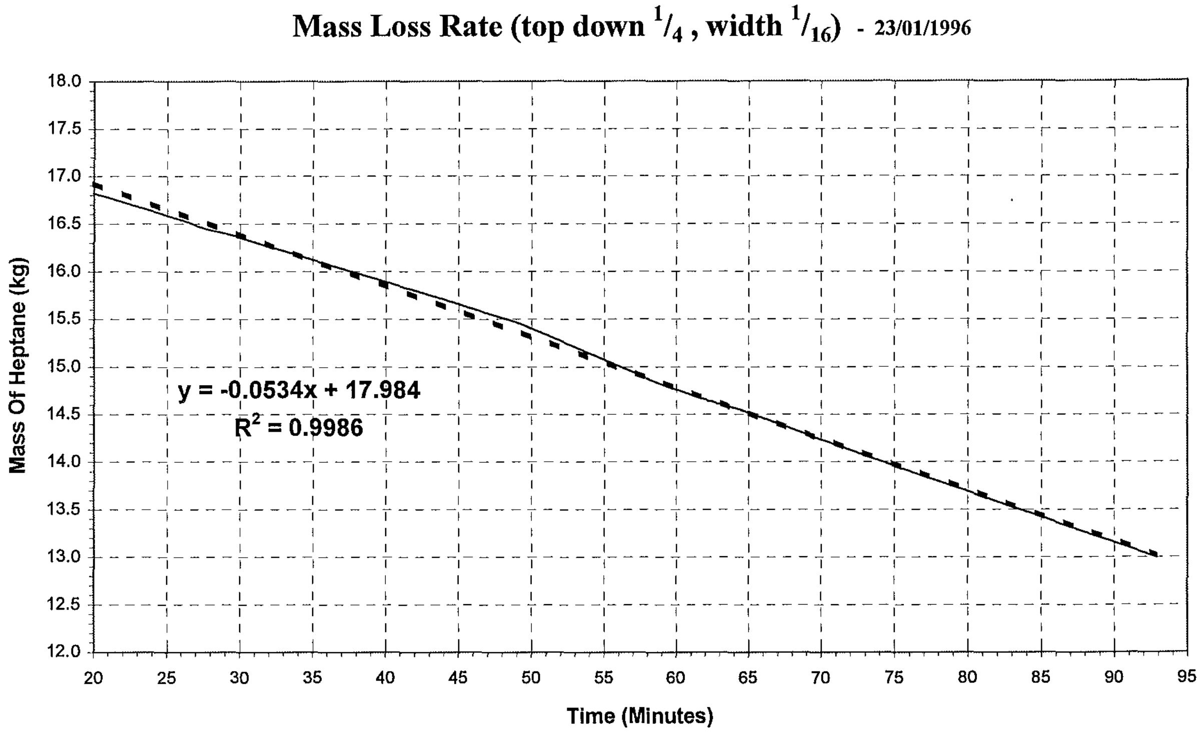
Ventilation Opening: Height - Top Down $^1/_4$
Width - $^1/_{16}$

Weather Conditions:

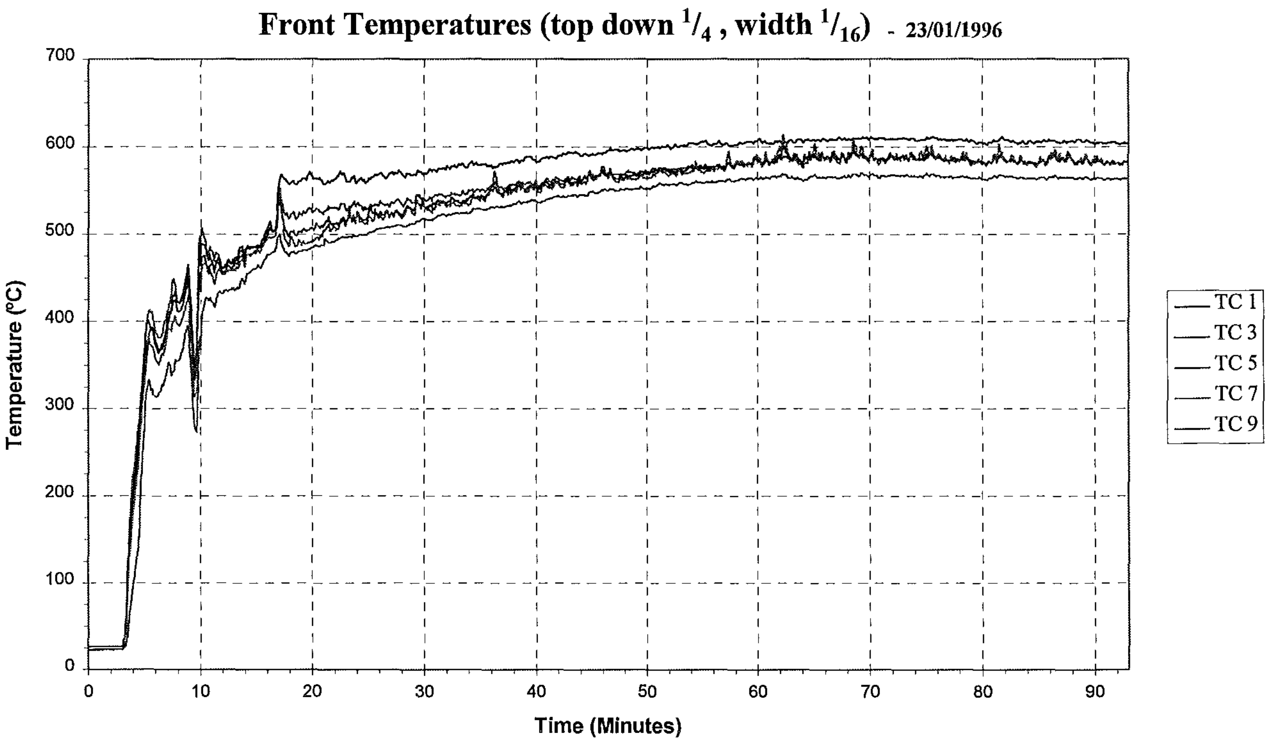
Average wind speed	=	1.0 m/s
Maximum wind speed	=	2.1 m/s

Comments: This experiment was repeated, as mass loss data was not recorded the first time.

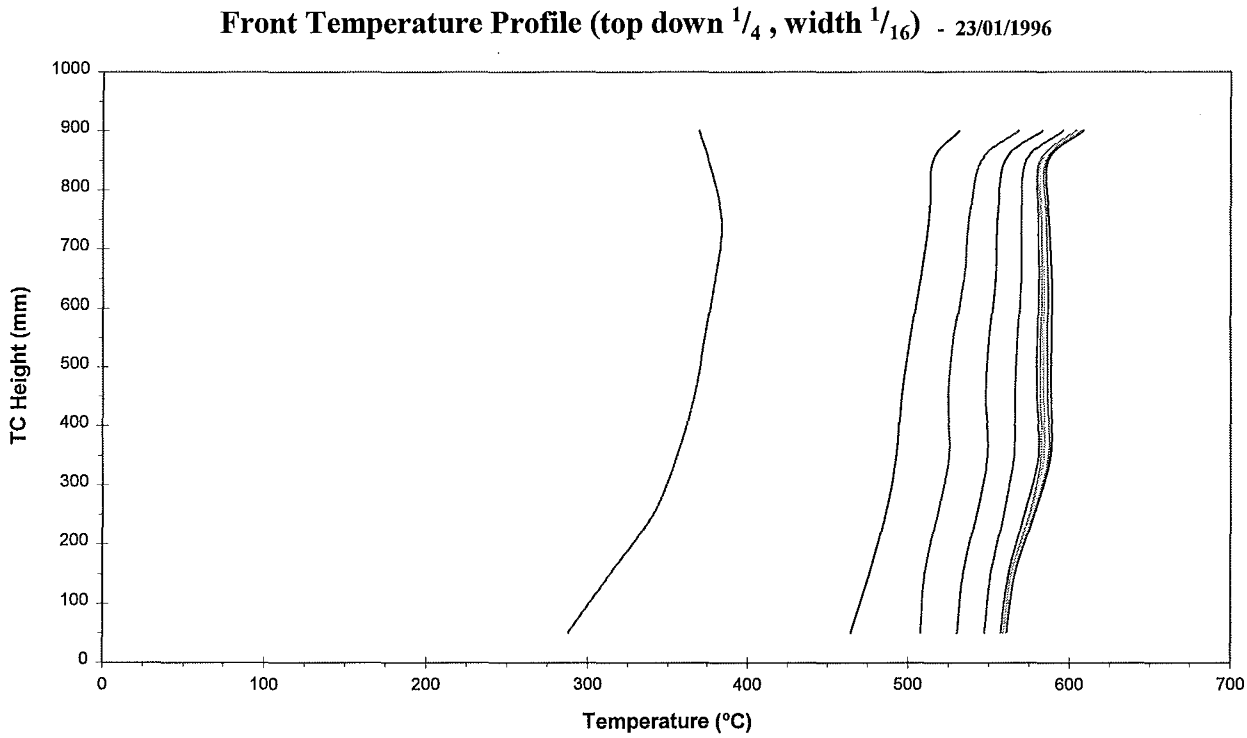


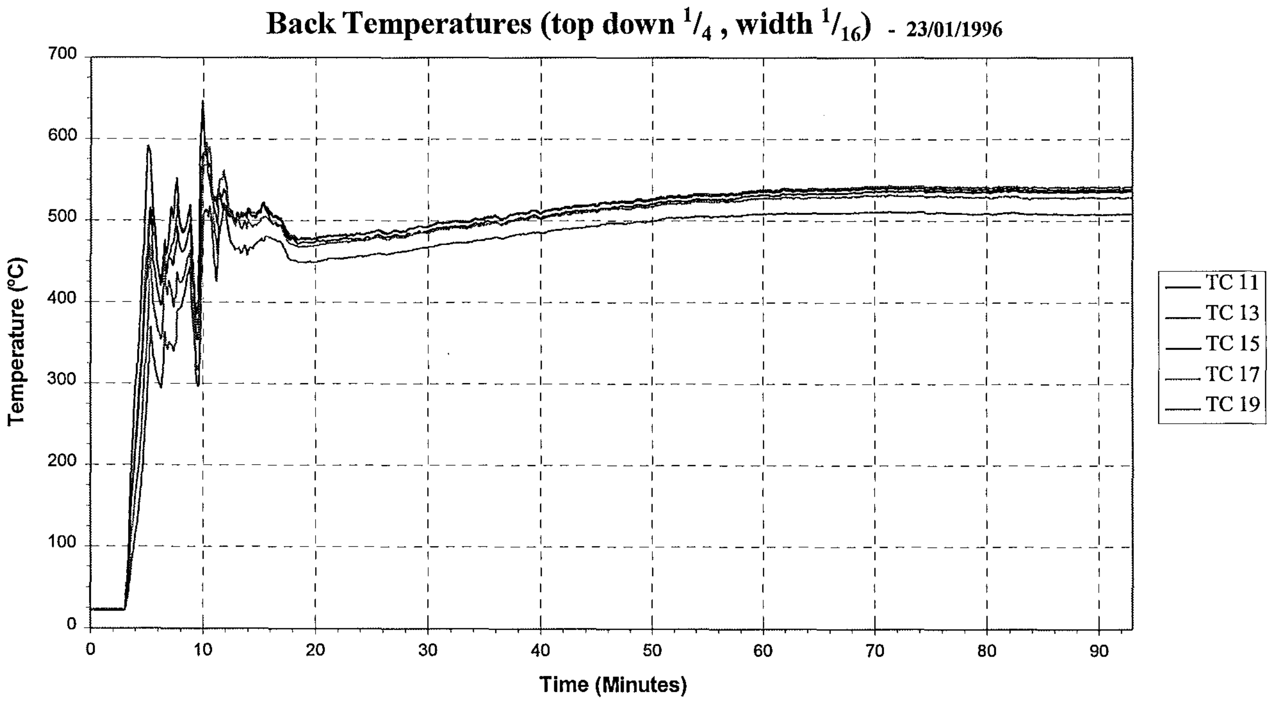


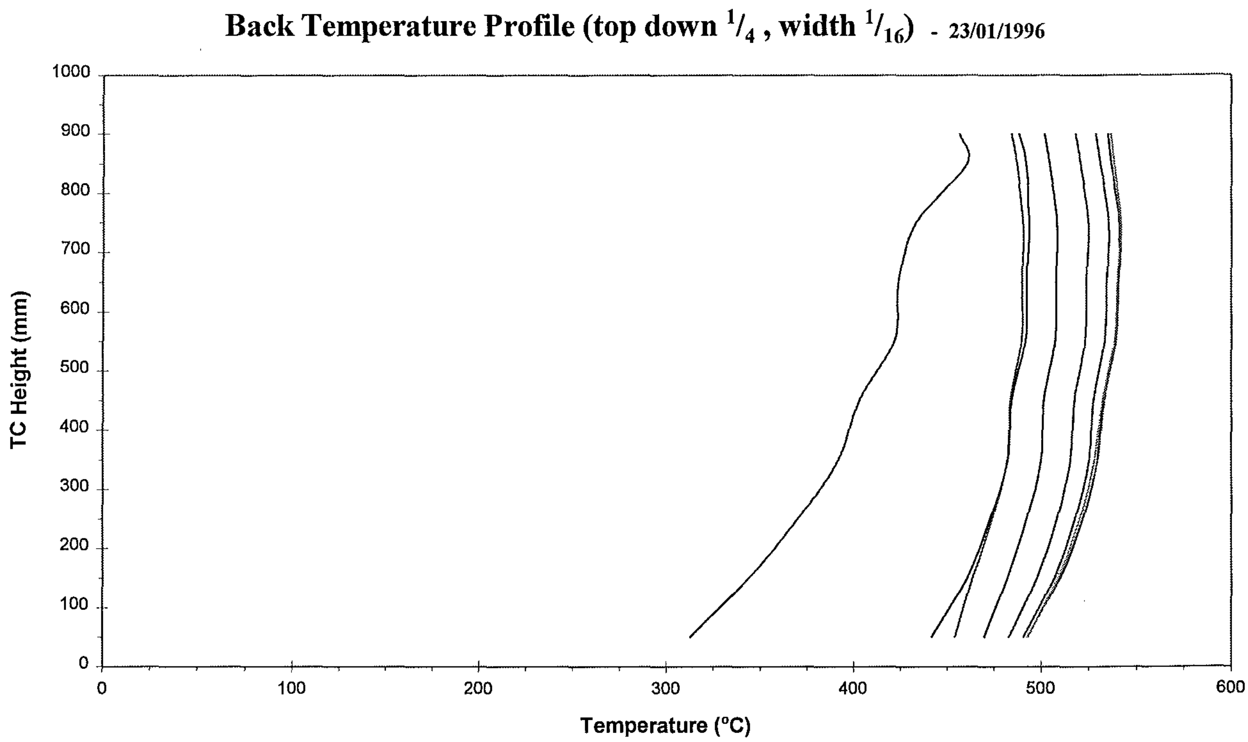
Mass Loss Rate (top down 1/4 , width 1/16) - 23/01/1996
y = -0.0534x + 17.984
R² = 0.9986
Mass Of Heptane (kg)
Time (Minutes)
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95

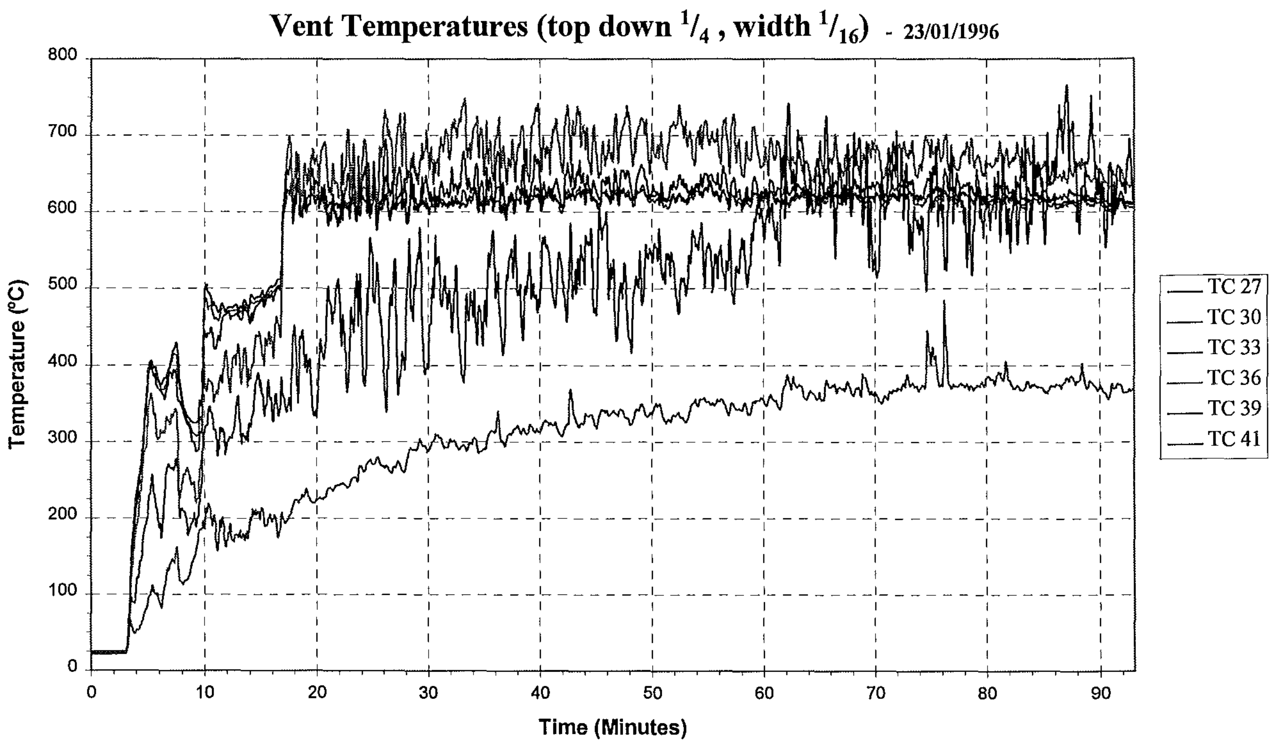


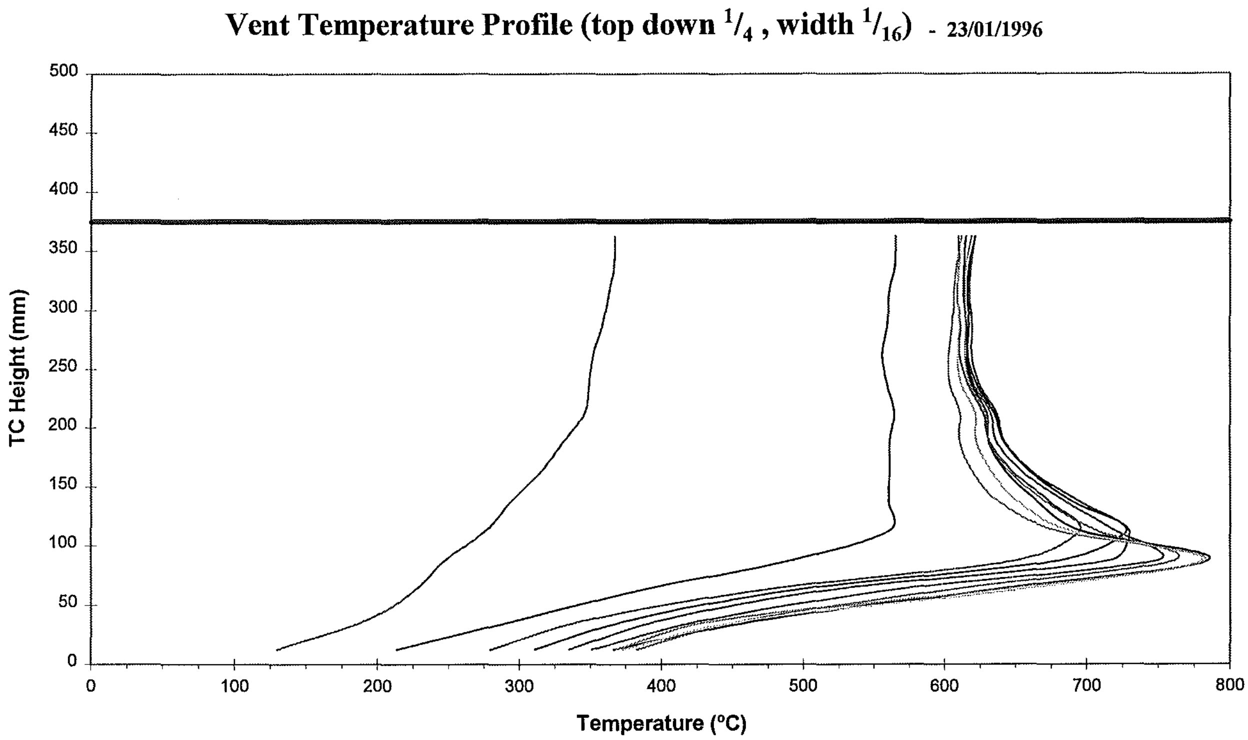
Front Temperatures (top down 1/4 , width 1/16) - 23/01/1996
Temperature (ºC)
Time (Minutes)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
TC 1
TC 3
TC 5
TC 7
TC 9

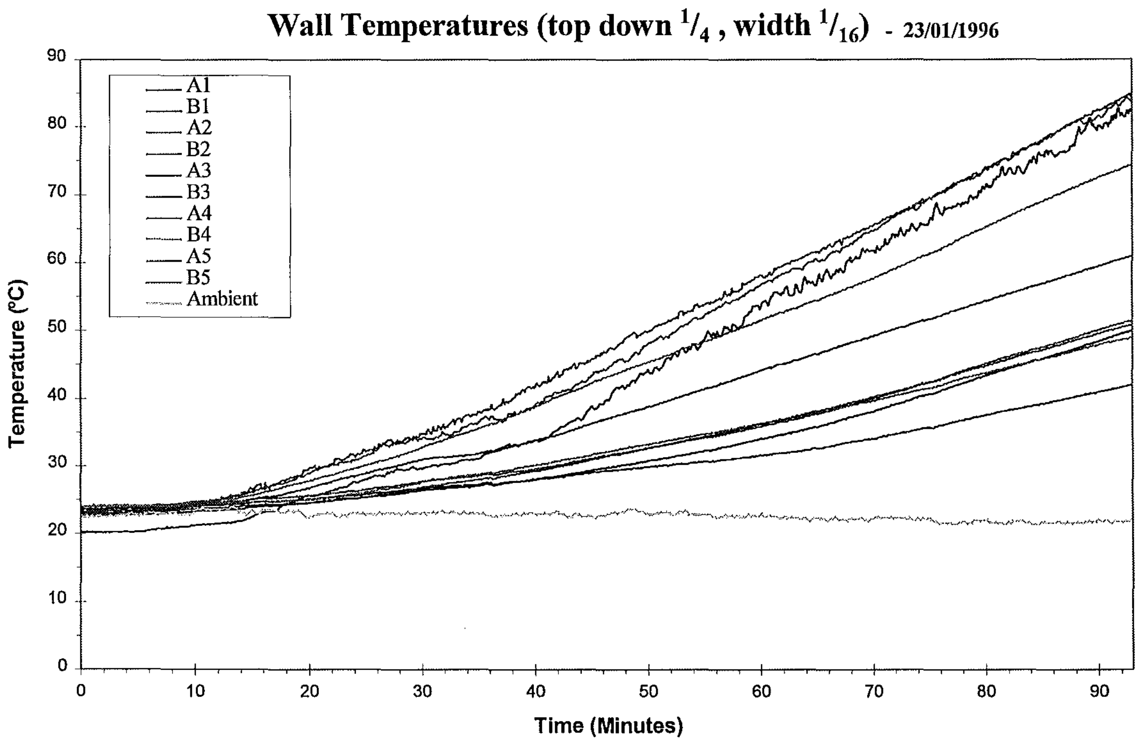

Front Temperature Profile (top down 1/4 , width 1/16) - 23/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000


Back Temperatures (top down 1/4 , width 1/16) - 23/01/1996
Temperature (°C)
Time (Minutes)
TC 11
TC 13
TC 15
TC 17
TC 19
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700


Back Temperature Profile (top down 1/4, width 1/16) - 23/01/1996
TC Height (mm)
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
Temperature (°C)


Vent Temperatures (top down 1/4, width 1/16) - 23/01/1996
Temperature (°C)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
Time (Minutes)
TC 27
TC 30
TC 33
TC 36
TC 39
TC 41


Vent Temperature Profile (top down $^1/_4$, width $^1/_{16}$) - 23/01/1996
500
450
400
350
300
250
200
150
100
50
0
TC Height (mm)
0
100
200
300
400
500
600
700
800
Temperature (°C)


Wall Temperatures (top down $^1/_4$, width $^1/_{16}$) - 23/01/1996
A1
B1
A2
B2
A3
B3
A4
B4
A5
B5
Ambient
90
80
70
60
50
40
30
20
10
0
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
Time (Minutes)

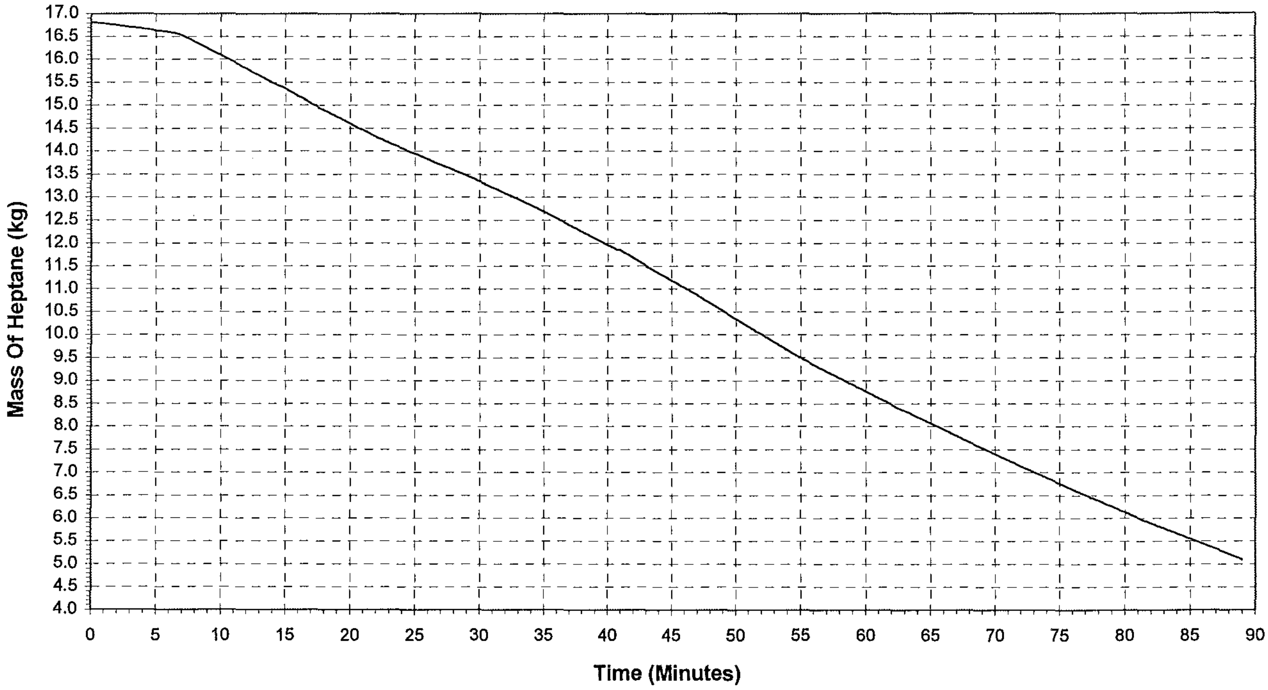
TEST #14

Ventilation Opening: Height - Full
Width - $^1/_4$

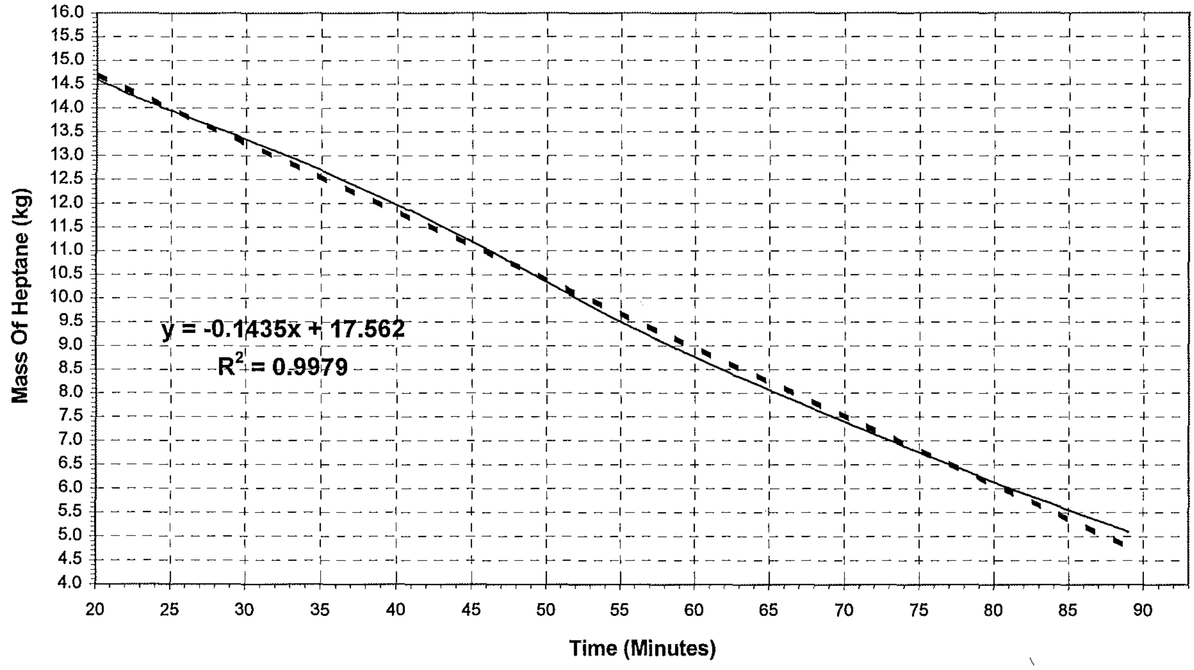
Weather Conditions: Average wind speed = 1.0 m/s
Maximum wind speed = 2.1 m/s

Comments: This experiment was repeated due to a constant head not being kept in the pan in the first run.

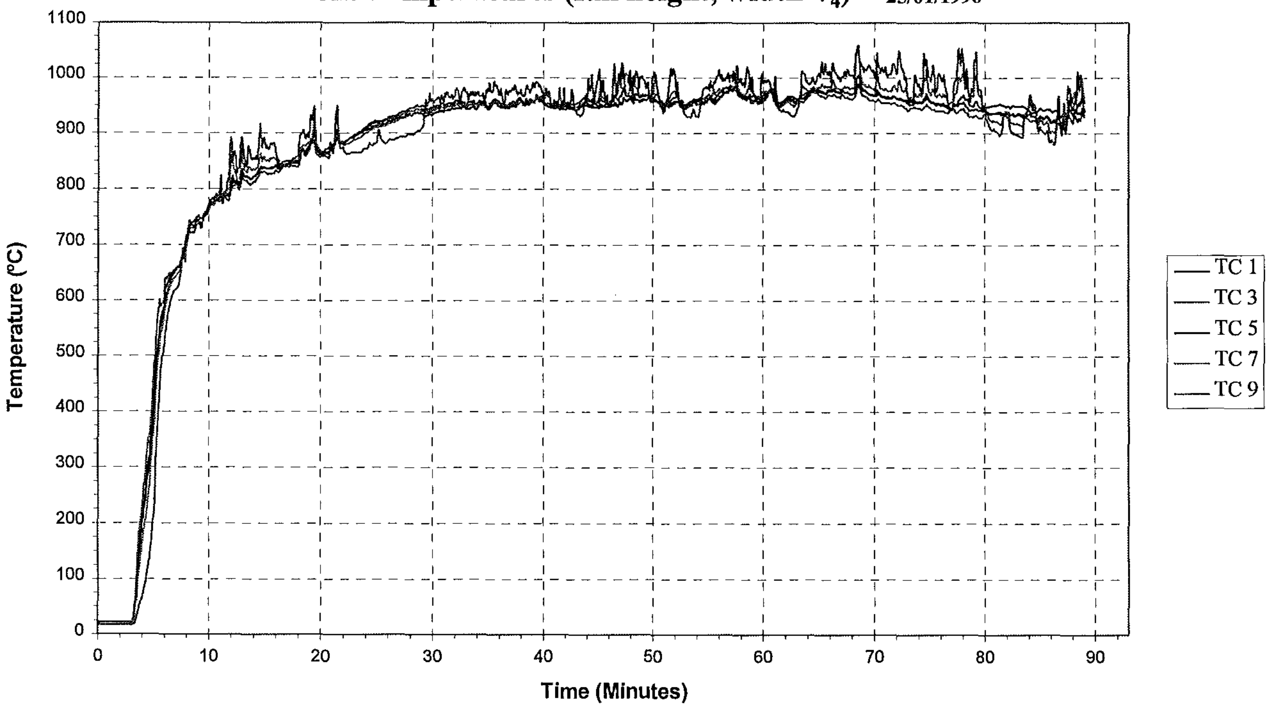
Heptane Mass Loss (full height, width $^1/_8$) - 25/01/1996



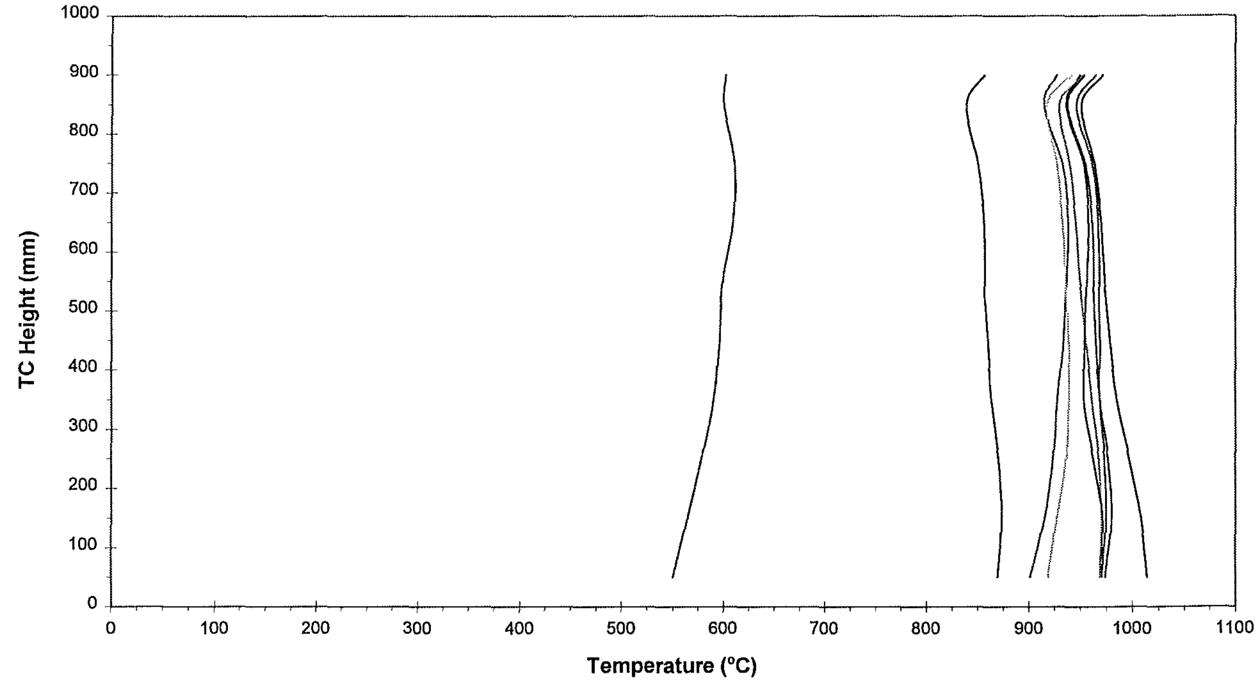
Mass Loss Rate (full height, width $^1/_4$) - 25/01/1996



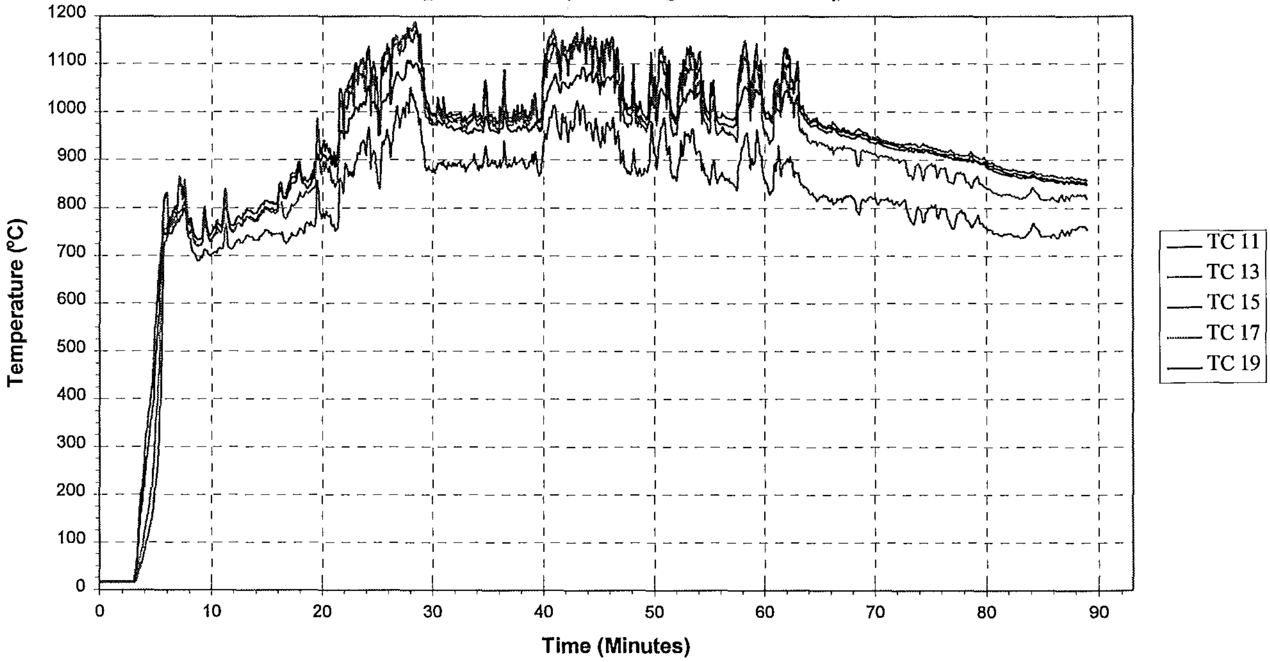
Front Temperatures (full height, width $^1/_4$) - 25/01/1996

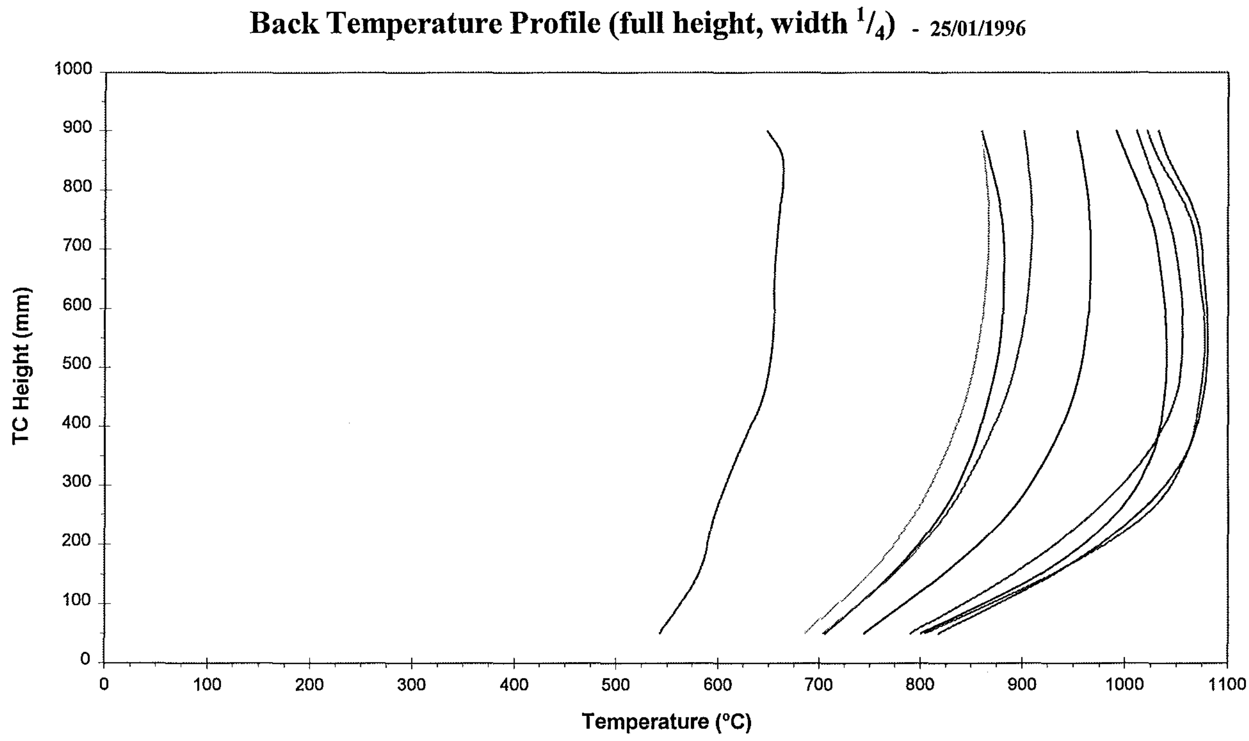


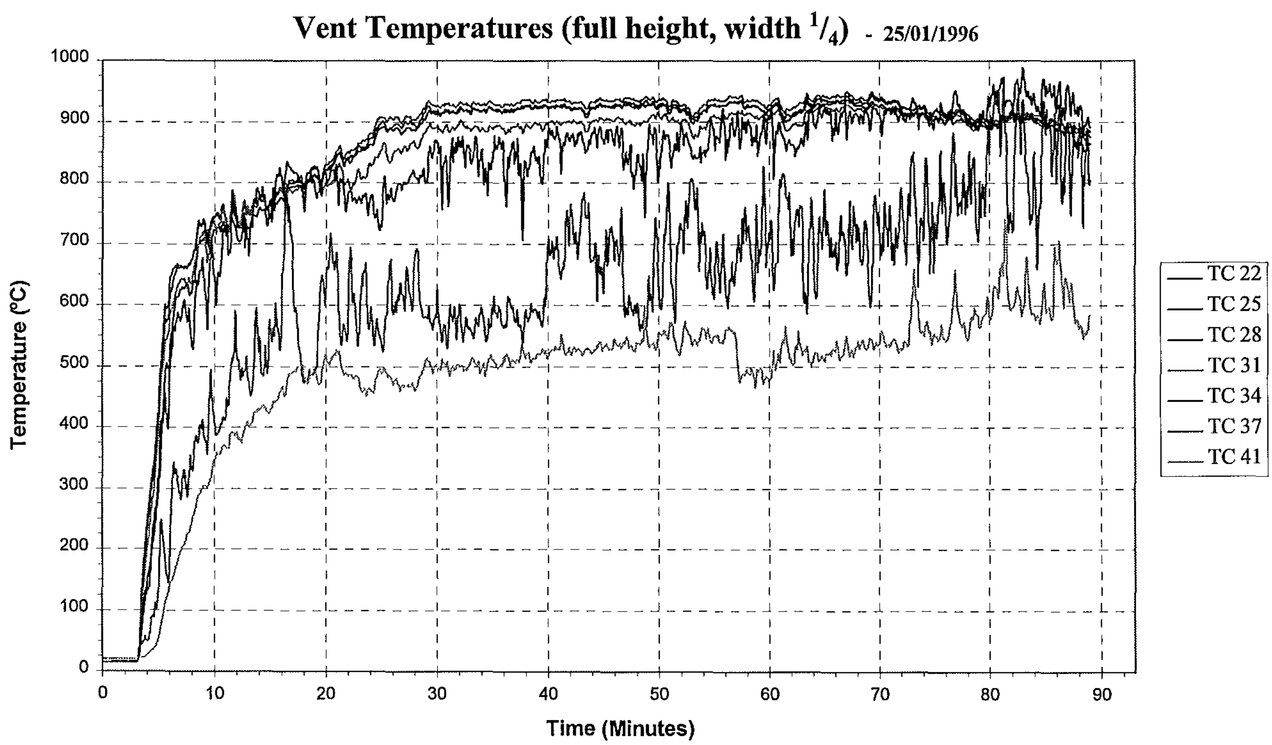
Front Temperature Profile (full height, width 1/4) - 25/01/1996



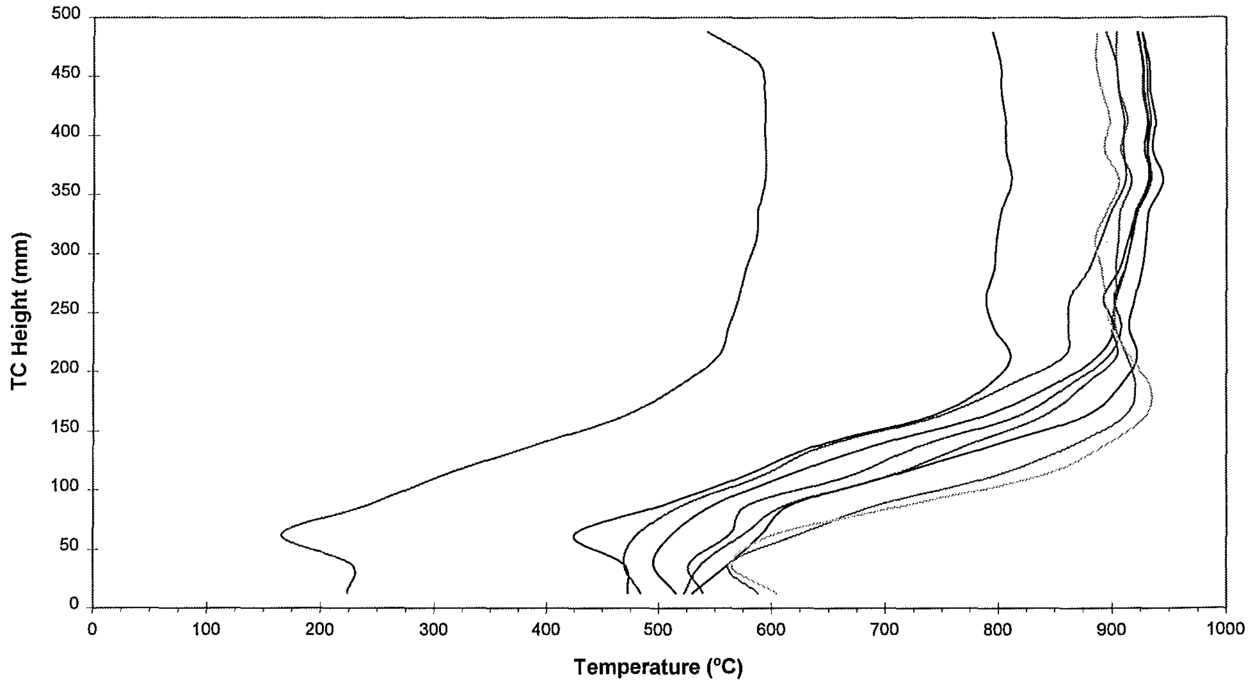
Back Temperatures (full height, width 1/4) - 25/01/1996



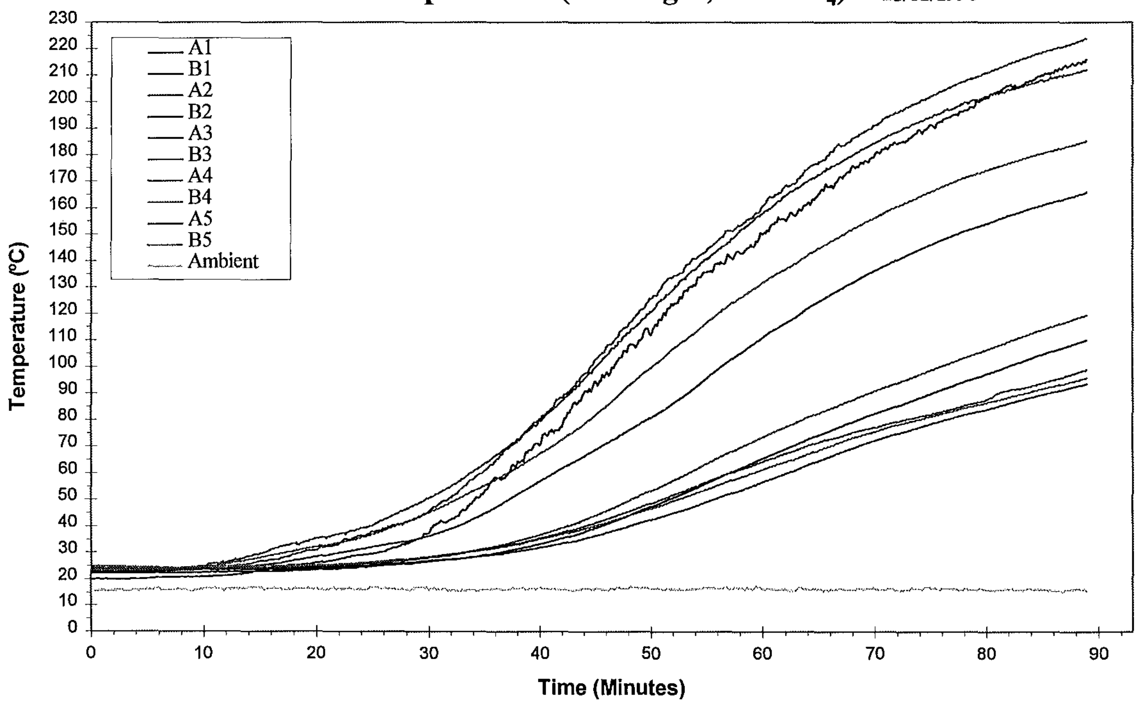

Back Temperature Profile (full height, width 1/4) - 25/01/1996
TC Height (mm)
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
1000
1100


Vent Temperatures (full height, width 1/4) - 25/01/1996
Temperature (°C)
Time (Minutes)
TC 22
TC 25
TC 28
TC 31
TC 34
TC 37
TC 41

Vent Temperature Profile (full height, width 1/4) - 25/01/1996



Wall Temperatures (full height, width 1/4) - 25/01/1996

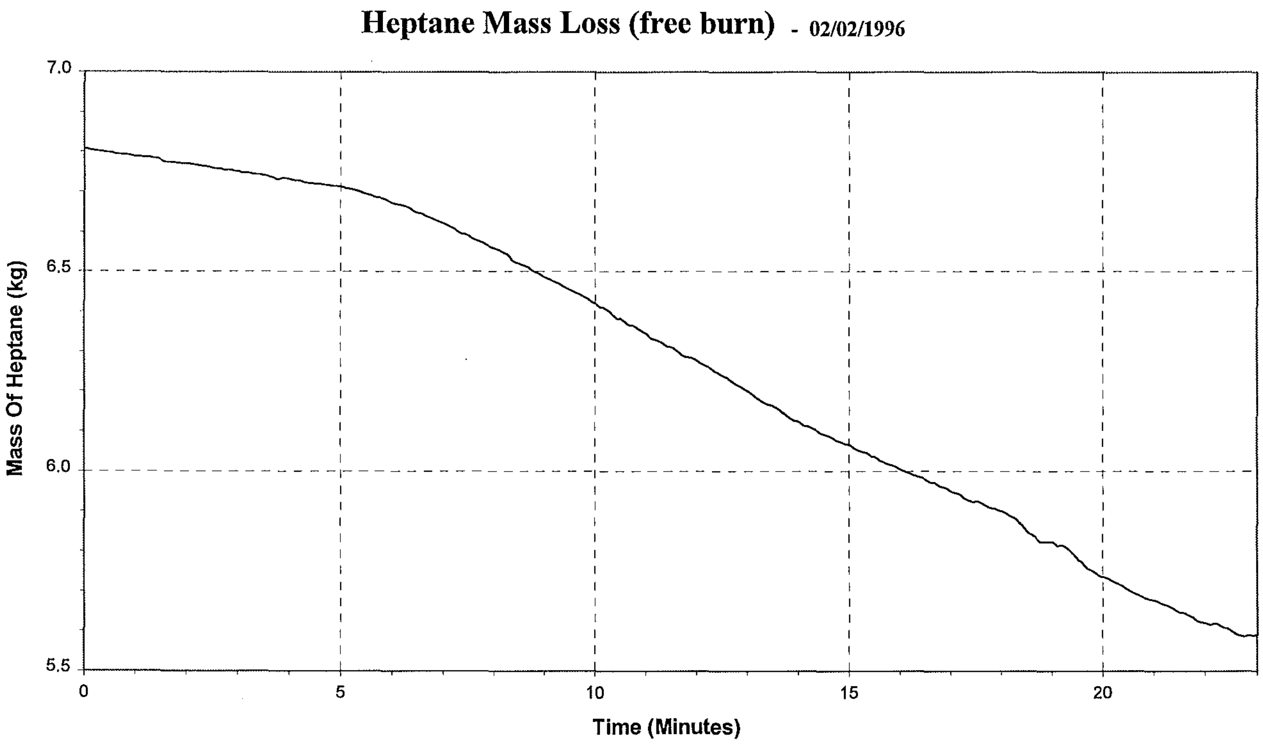


TEST #15

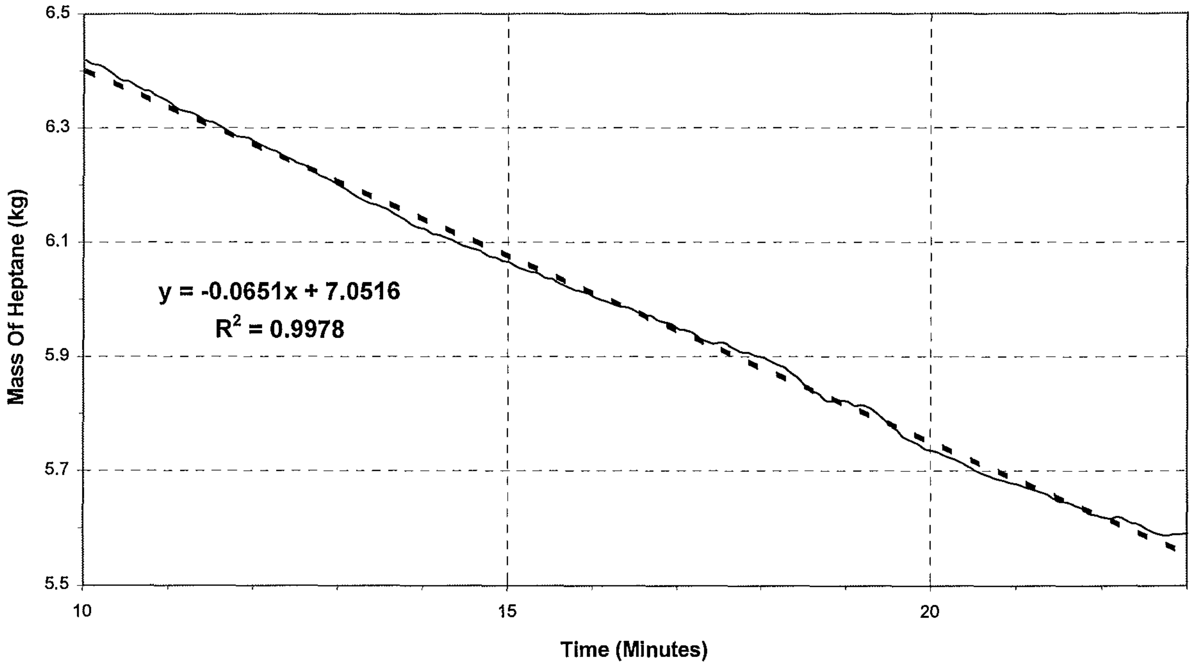
Ventilation Opening: N/A

Weather Conditions: Not Recorded.

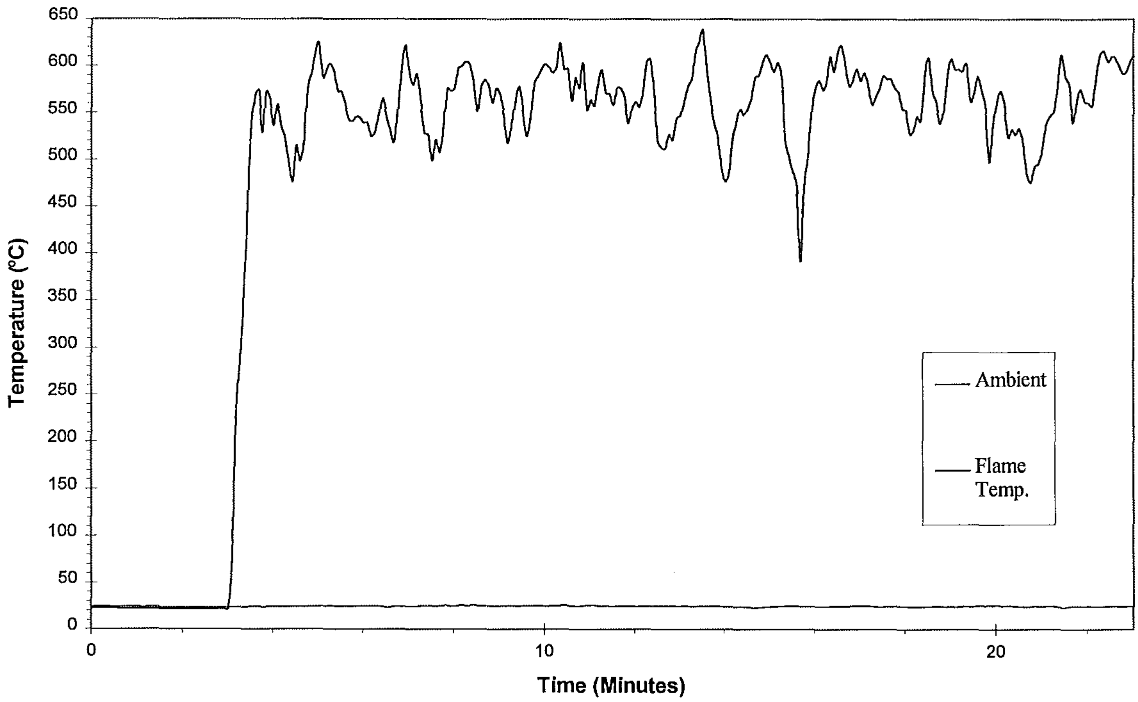
Comments:



Mass Loss Rate (free burn) - 02/02/1996



Temperatures (free burn) - 02/02/1996



Appendix E. CFAST Results

E1. Typical Input.

E2. Results.

E2

```
VERSN    2 TEST01 - FULL HEIGHT, WIDTH 1/4
TIMES   5400   150    60    60     0
TAMB   293.  101300.       0.
EAMB   293.  101300.       0.
HI/F     0.00
WIDTH    0.95
DEPTH    1.48
HEIGH    0.98
HVENT   1  2  1   0.125   0.750   0.250   0.000
CVENT   1  2  1   1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
  => 1.00
CEILI KAOWOOL
WALLS KAOWOOL
FLOOR GYP3/4
CHEMI    16.   20.    1.0    44600000.  300. 400. 0.000
LFBO   1
LFBT   2
FPOS    0.28   0.47   0.05
FTIME     10.     20.     30.     40.     50.     60.     70.     80.     90.
FMASS  0.0023 0.0023 0.0023 0.0023 0.0023 0.0023 0.0023 0.0023 0.0023 0.0023
FHIGH    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
FAREA    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
FQDOT  1.05E+05 1.05E+05 1.05E+05 1.05E+05 1.05E+05 1.05E+05 1.05E+05 1.05E+05 1
  => .05E+05 1.05E+05
CJET ALL
HCR   0.333 0.333 0.333 0.333 0.333 0.333 0.333 0.333 0.333 0.333
STPMAX  5.00
DUMPR COMPF4.HIS
WINDOW        -50      0  -100  1280  1024   1100
GRAPH 1  100.  050.  0.  600.  475.  10.  3 TIME  HEIGHT
GRAPH 2  100.  550.  0.  600.  940.  10.  3 TIME  CELSIUS
GRAPH 3  720.  050.  0.  1250. 475.  10.  3 TIME  FIRE_SIZE(kW)
GRAPH 4  720.  550.  0.  1250. 940.  10.  3 TIME  O!D2!O(%)
INTERFA 0 0 0 0 1     1 U
TEMPERA 0 0 0 0 2     1 U
HEAT    0 0 0 0 3     1 U
O2      0 0 0 0 4     1 U
```


ICI4PRINT

```
**      CFAST  Version   2.0.1  Run  2/26/96       **
**                                                 **
**             A contribution of the               **
** National Institute of Standards and Technology  **
**             Gaithersburg, MD  20899             **
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```

Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	2.300E-03	1.050E+05
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	866.3	553.5	7.55E-02	2.300E-03	6.590E+04
Outside					3.978E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	985.5	627.7	7.53E-02	2.300E-03	6.564E+04
Outside					3.982E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1079.	693.7	7.67E-02	2.300E-03	6.512E+04
Outside					4.015E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1156.	748.5	7.79E-02	2.300E-03	6.457E+04
Outside					4.061E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1221.	795.6	7.89E-02	2.300E-03	6.407E+04
Outside					4.107E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1277.	836.6	7.97E-02	2.300E-03	6.361E+04
Outside					4.149E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1325.	872.5	8.04E-02	2.300E-03	6.321E+04
Outside					4.187E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1366.	903.9	8.10E-02	2.300E-03	6.285E+04
Outside					4.220E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1402.	931.7	8.15E-02	2.300E-03	6.256E+04
Outside					4.250E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1434.	956.3	8.20E-02	2.300E-03	6.226E+04
Outside					4.278E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1461.	978.2	8.24E-02	2.300E-03	6.204E+04
Outside					4.300E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1486.	997.9	8.28E-02	2.300E-03	6.180E+04
Outside					4.320E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1508.	1016.	8.31E-02	2.300E-03	6.164E+04
Outside					4.339E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1528.	1032.	8.33E-02	2.300E-03	6.147E+04
Outside					4.356E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1546.	1046.	8.36E-02	2.300E-03	6.132E+04
Outside					4.371E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1562.	1059.	8.38E-02	2.300E-03	6.118E+04
Outside					4.383E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1576.	1071.	8.40E-02	2.300E-03	6.106E+04
Outside					4.362E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1589.	1082.	8.42E-02	2.300E-03	6.094E+04
Outside					4.409E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1601.	1092.	8.43E-02	2.300E-03	6.095E+04
Outside					3.855E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1612.	1101.	8.45E-02	2.300E-03	6.075E+04
Outside					4.427E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1622.	1109.	8.47E-02	2.300E-03	6.067E+04
Outside					4.435E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1631.	1116.	8.48E-02	2.300E-03	6.058E+04
Outside					4.442E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1639.	1123.	8.49E-02	2.300E-03	6.052E+04
Outside					4.449E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1646.	1129.	8.50E-02	2.300E-03	6.046E+04
Outside					4.455E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1653.	1135.	8.50E-02	2.300E-03	6.062E+04
Outside					4.469E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1659.	1140.	8.52E-02	2.300E-03	6.036E+04
Outside					4.466E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1665.	1145.	8.53E-02	2.300E-03	6.036E+04
Outside					4.474E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1670.	1149.	8.54E-02	2.300E-03	6.026E+04
Outside					4.475E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1674.	1153.	8.54E-02	2.300E-03	6.025E+04
Outside					4.480E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1678.	1156.	8.55E-02	2.300E-03	6.019E+04
Outside					4.482E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1682.	1160.	8.55E-02	2.300E-03	6.015E+04
Outside					4.485E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1686.	1163.	8.56E-02	2.300E-03	6.012E+04
Outside					4.488E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1689.	1165.	8.56E-02	2.300E-03	6.008E+04
Outside					4.489E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1692.	1168.	8.57E-02	2.300E-03	6.008E+04
Outside					4.493E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1694.	1170.	8.57E-02	2.300E-03	6.005E+04
Outside					4.494E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1697.	1172.	8.57E-02	2.300E-03	6.004E+04
Outside					4.496E+04

Result for ventilation opening 500mm high, 125mm wide

Result for ventilation opening 500mm high, 62.5mm wide

```
**      CFAST  Version   2.0.1  Run  2/21/96      **
**                                                **
**            A contribution of the               **
** National Institute of Standards and Technology **
**            Gaithersburg, MD  20899             **
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```

Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	1.700E-03	7.600E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	673.1	512.5	7.82E-02	1.700E-03	3.199E+04
Outside					3.822E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	727.2	550.0	7.70E-02	1.700E-03	3.229E+04
Outside					4.453E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	776.0	585.6	7.64E-02	1.700E-03	3.244E+04
Outside					4.450E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	820.4	617.5	7.59E-02	1.700E-03	3.249E+04
Outside					4.423E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	860.8	646.2	7.56E-02	1.700E-03	3.248E+04
Outside					4.409E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	897.5	671.9	7.55E-02	1.700E-03	3.244E+04
Outside					4.401E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	930.6	695.1	7.53E-02	1.700E-03	3.238E+04
Outside					4.398E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	960.6	716.1	7.53E-02	1.700E-03	3.232E+04
Outside					4.399E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	987.8	735.1	7.52E-02	1.700E-03	3.225E+04
Outside					4.401E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1012.	752.4	7.52E-02	1.700E-03	3.218E+04
Outside					4.404E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1035.	768.1	7.52E-02	1.700E-03	3.210E+04
Outside					4.409E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1055.	782.5	7.51E-02	1.700E-03	3.204E+04
Outside					4.413E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1074.	795.7	7.51E-02	1.700E-03	3.198E+04
Outside					4.418E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1091.	807.8	7.51E-02	1.700E-03	3.191E+04
Outside					4.422E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1106.	818.9	7.51E-02	1.700E-03	3.185E+04
Outside					4.426E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1121.	829.2	7.52E-02	1.700E-03	3.178E+04
Outside					4.430E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1134.	838.7	7.52E-02	1.700E-03	3.174E+04
Outside					4.435E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1146.	847.4	7.52E-02	1.700E-03	3.170E+04
Outside					4.439E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1157.	855.5	7.52E-02	1.700E-03	3.165E+04
Outside					4.442E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1167.	863.0	7.52E-02	1.700E-03	3.161E+04
Outside					4.446E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1177.	869.9	7.52E-02	1.700E-03	3.157E+04
Outside					4.449E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1186.	876.3	7.52E-02	1.700E-03	3.154E+04
Outside					4.452E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1194.	882.3	7.52E-02	1.700E-03	3.150E+04
Outside					4.455E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1201.	887.7	7.52E-02	1.700E-03	3.147E+04
Outside					4.458E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1208.	892.8	7.52E-02	1.700E-03	3.144E+04
Outside					4.460E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1215.	897.5	7.52E-02	1.700E-03	3.141E+04
Outside					4.463E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1220.	901.9	7.53E-02	1.700E-03	3.138E+04
Outside					4.465E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1226.	905.9	7.53E-02	1.700E-03	3.136E+04
Outside					4.467E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1231.	909.6	7.53E-02	1.700E-03	3.136E+04
Outside					4.468E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1236.	913.1	7.53E-02	1.700E-03	3.132E+04
Outside					4.471E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1240.	916.3	7.53E-02	1.700E-03	3.133E+04
Outside					4.473E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1244.	919.2	7.53E-02	1.700E-03	3.128E+04
Outside					4.474E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1248.	922.0	7.53E-02	1.700E-03	3.127E+04
Outside					4.476E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1251.	924.5	7.53E-02	1.700E-03	3.125E+04
Outside					4.476E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1254.	926.8	7.53E-02	1.700E-03	3.124E+04
Outside					4.478E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1257.	929.0	7.53E-02	1.700E-03	3.123E+04
Outside					4.479E+04

Result for ventilation opening 500mm high, 62.5mm wide

Result for ventilation opening 500mm high, 31.25mm wide

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**      CFAST  Version   2.0.1  Run  2/21/96       **
**                                                 **
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**            Gaithersburg, MD  20899              **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	1.100E-03	5.030E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	554.9	463.4	8.11E-02	1.100E-03	1.541E+04
Outside					1.607E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	565.2	477.4	8.13E-02	1.100E-03	1.484E+04
Outside					2.945E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	585.7	495.8	8.13E-02	1.100E-03	1.496E+04
Outside					3.431E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	606.7	513.6	8.13E-02	1.100E-03	1.510E+04
Outside					3.577E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	626.5	529.4	8.13E-02	1.100E-03	1.522E+04
Outside					3.604E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	645.2	544.8	8.13E-02	1.100E-03	1.531E+04
Outside					3.595E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	662.9	559.6	8.13E-02	1.100E-03	1.539E+04
Outside					3.579E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	679.5	573.3	8.11E-02	1.100E-03	1.544E+04
Outside					3.562E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	695.1	585.9	8.08E-02	1.100E-03	1.549E+04
Outside					3.548E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	709.7	597.7	8.06E-02	1.100E-03	1.553E+04
Outside					3.536E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	723.4	608.8	8.04E-02	1.100E-03	1.555E+04
Outside					3.526E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	736.3	619.2	8.03E-02	1.100E-03	1.558E+04
Outside					3.518E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	748.3	628.9	8.02E-02	1.100E-03	1.560E+04
Outside					3.511E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	759.7	638.0	8.00E-02	1.100E-03	1.561E+04
Outside					3.506E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	770.3	646.5	8.00E-02	1.100E-03	1.562E+04
Outside					3.501E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	780.2	654.5	7.99E-02	1.100E-03	1.563E+04
Outside					3.497E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	789.6	662.0	7.98E-02	1.100E-03	1.563E+04
Outside					3.493E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	798.3	669.0	7.98E-02	1.100E-03	1.563E+04
Outside					3.491E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	806.6	675.6	7.97E-02	1.100E-03	1.564E+04
Outside					3.489E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	814.3	681.8	7.97E-02	1.100E-03	1.564E+04
Outside					3.486E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	821.6	687.6	7.97E-02	1.100E-03	1.564E+04
Outside					3.485E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	828.4	693.1	7.96E-02	1.100E-03	1.564E+04
Outside					3.483E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	834.7	698.2	7.96E-02	1.100E-03	1.564E+04
Outside					3.482E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	840.7	703.0	7.96E-02	1.100E-03	1.564E+04
Outside					3.481E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	846.4	707.5	7.96E-02	1.100E-03	1.563E+04
Outside					3.480E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	851.6	711.7	7.96E-02	1.100E-03	1.563E+04
Outside					3.479E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	856.6	715.7	7.96E-02	1.100E-03	1.563E+04
Outside					3.478E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	861.3	719.4	7.96E-02	1.100E-03	1.563E+04
Outside					3.478E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	865.6	722.9	7.95E-02	1.100E-03	1.562E+04
Outside					3.477E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	869.7	726.2	7.95E-02	1.100E-03	1.562E+04
Outside					3.477E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	873.6	729.3	7.95E-02	1.100E-03	1.562E+04
Outside					3.476E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	877.2	732.2	7.95E-02	1.100E-03	1.562E+04
Outside					3.476E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	880.5	734.9	7.95E-02	1.100E-03	1.561E+04
Outside					3.476E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	883.7	737.5	7.95E-02	1.100E-03	1.561E+04
Outside					3.475E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	886.7	739.9	7.95E-02	1.100E-03	1.561E+04
Outside					3.475E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	889.5	742.1	7.95E-02	1.100E-03	1.561E+04
Outside					3.475E+04

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**      CFAST  Version   2.0.1  Run  2/21/96      **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	2.100E-03	9.190E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	732.5	481.4	6.68E-02	2.100E-03	4.165E+04
Outside					4.864E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	805.8	529.3	6.60E-02	2.100E-03	4.193E+04
Outside					5.103E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	868.6	567.4	6.56E-02	2.100E-03	4.194E+04
Outside					5.072E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	924.1	605.9	6.61E-02	2.100E-03	4.186E+04
Outside					5.058E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	973.2	639.9	6.65E-02	2.100E-03	4.172E+04
Outside					5.060E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1017.	669.9	6.69E-02	2.100E-03	4.156E+04
Outside					5.066E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1056.	696.7	6.73E-02	2.100E-03	4.140E+04
Outside					5.076E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1090.	720.7	6.76E-02	2.100E-03	4.123E+04
Outside					5.087E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1121.	742.3	6.79E-02	2.100E-03	4.110E+04
Outside					5.099E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1148.	761.7	6.81E-02	2.100E-03	4.095E+04
Outside					5.110E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1173.	779.4	6.83E-02	2.100E-03	4.082E+04
Outside					5.120E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1195.	795.4	6.85E-02	2.100E-03	4.073E+04
Outside					5.131E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1215.	810.0	6.87E-02	2.100E-03	4.060E+04
Outside					5.140E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1234.	823.3	6.89E-02	2.100E-03	4.049E+04
Outside					5.148E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1250.	835.5	6.90E-02	2.100E-03	4.043E+04
Outside					5.157E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1265.	846.7	6.92E-02	2.100E-03	4.032E+04
Outside					5.164E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1279.	857.0	6.93E-02	2.100E-03	4.027E+04
Outside					5.172E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1292.	866.4	6.94E-02	2.100E-03	4.017E+04
Outside					5.178E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1303.	875.1	6.95E-02	2.100E-03	4.013E+04
Outside					5.186E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1314.	883.1	6.96E-02	2.100E-03	4.005E+04
Outside					5.189E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1324.	890.5	6.97E-02	2.100E-03	3.998E+04
Outside					5.194E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1333.	897.3	6.97E-02	2.100E-03	3.994E+04
Outside					5.199E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1341.	903.5	6.98E-02	2.100E-03	3.991E+04
Outside					5.209E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1349.	909.3	6.99E-02	2.100E-03	3.985E+04
Outside					5.208E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1355.	914.6	6.99E-02	2.100E-03	3.981E+04
Outside					5.211E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1362.	919.4	7.00E-02	2.100E-03	3.978E+04
Outside					5.215E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1368.	923.9	7.00E-02	2.100E-03	3.975E+04
Outside					5.218E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1373.	928.1	7.01E-02	2.100E-03	3.972E+04
Outside					5.219E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1378.	931.9	7.01E-02	2.100E-03	3.968E+04
Outside					5.179E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1382.	935.4	7.02E-02	2.100E-03	3.966E+04
Outside					5.242E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1387.	938.6	7.02E-02	2.100E-03	3.963E+04
Outside					5.225E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1390.	941.6	7.02E-02	2.100E-03	3.960E+04
Outside					5.230E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1394.	944.3	7.03E-02	2.100E-03	3.957E+04
Outside					5.231E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1397.	946.8	7.03E-02	2.100E-03	3.957E+04
Outside					5.234E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1400.	949.1	7.03E-02	2.100E-03	3.956E+04
Outside					5.235E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1403.	951.2	7.04E-02	2.100E-03	3.954E+04
Outside					5.258E+04

Result for ventilation opening 375mm high, 125mm wide

Result for ventilation opening 375mm high, 62.5mm wide

```
**      CFAST  Version   2.0.1  Run  2/21/96       **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	1.100E-03	5.120E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	595.2	454.5	6.94E-02	1.100E-03	2.075E+04
Outside					1.796E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	622.6	476.8	6.93E-02	1.100E-03	2.059E+04
Outside					2.870E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	653.2	500.7	6.92E-02	1.100E-03	2.077E+04
Outside					3.092E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	682.4	523.3	6.89E-02	1.100E-03	2.091E+04
Outside					3.110E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	709.9	543.7	6.85E-02	1.100E-03	2.101E+04
Outside					3.094E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	735.5	562.4	6.81E-02	1.100E-03	2.108E+04
Outside					3.075E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	759.3	579.5	6.79E-02	1.100E-03	2.113E+04
Outside					3.060E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	781.3	595.3	6.77E-02	1.100E-03	2.116E+04
Outside					3.049E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	801.8	609.7	6.75E-02	1.100E-03	2.117E+04
Outside					3.040E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	820.8	623.0	6.74E-02	1.100E-03	2.118E+04
Outside					3.035E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	838.4	635.3	6.73E-02	1.100E-03	2.118E+04
Outside					3.030E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	854.7	646.6	6.72E-02	1.100E-03	2.118E+04
Outside					3.027E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	869.8	657.1	6.71E-02	1.100E-03	2.117E+04
Outside					3.025E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	883.9	666.8	6.70E-02	1.100E-03	2.116E+04
Outside					3.024E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	896.9	675.8	6.70E-02	1.100E-03	2.115E+04
Outside					3.023E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	909.1	684.2	6.70E-02	1.100E-03	2.113E+04
Outside					3.022E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	920.4	692.0	6.69E-02	1.100E-03	2.112E+04
Outside					3.022E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	930.9	699.3	6.69E-02	1.100E-03	2.111E+04
Outside					3.022E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	940.7	706.1	6.69E-02	1.100E-03	2.109E+04
Outside					3.022E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	949.8	712.4	6.68E-02	1.100E-03	2.108E+04
Outside					3.023E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	958.4	718.4	6.68E-02	1.100E-03	2.106E+04
Outside					3.023E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	966.3	723.9	6.68E-02	1.100E-03	2.105E+04
Outside					3.024E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	973.7	729.0	6.68E-02	1.100E-03	2.104E+04
Outside					3.024E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	980.6	733.8	6.68E-02	1.100E-03	2.102E+04
Outside					3.025E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	987.1	738.3	6.67E-02	1.100E-03	2.101E+04
Outside					3.025E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	993.1	742.5	6.67E-02	1.100E-03	2.100E+04
Outside					3.026E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	998.7	746.5	6.67E-02	1.100E-03	2.099E+04
Outside					3.026E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1004.	750.1	6.67E-02	1.100E-03	2.098E+04
Outside					3.027E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1009.	753.5	6.67E-02	1.100E-03	2.097E+04
Outside					3.028E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1013.	756.7	6.67E-02	1.100E-03	2.096E+04
Outside					3.028E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1018.	759.7	6.67E-02	1.100E-03	2.095E+04
Outside					3.029E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1022.	762.5	6.67E-02	1.100E-03	2.094E+04
Outside					3.029E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1025.	765.1	6.67E-02	1.100E-03	2.094E+04
Outside					3.030E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1029.	767.5	6.67E-02	1.100E-03	2.093E+04
Outside					3.030E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1032.	769.8	6.67E-02	1.100E-03	2.092E+04
Outside					3.031E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1035.	771.9	6.67E-02	1.100E-03	2.091E+04
Outside					3.031E+04

Result for ventilation opening 375mm high, 62.5mm wide

IC14PRINT

Result for ventilation opening 375mm high, 31.25mm wide

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**      CFAST  Version   2.0.1  Run  2/21/96        **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	9.000E-04	3.970E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	516.7	417.5	6.90E-02	9.000E-04	1.061E+04
Outside					7.224E+03

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	501.7	417.5	6.93E-02	9.000E-04	9.155E+03
Outside					1.798E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	508.2	424.3	6.93E-02	9.000E-04	8.996E+03
Outside					2.436E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	519.1	433.0	6.92E-02	9.000E-04	9.046E+03
Outside					2.795E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	530.6	441.5	6.92E-02	9.000E-04	9.134E+03
Outside					2.982E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	541.9	450.0	6.91E-02	9.000E-04	9.217E+03
Outside					3.073E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	552.7	458.7	6.91E-02	9.000E-04	9.292E+03
Outside					3.111E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	563.1	467.2	6.91E-02	9.000E-04	9.358E+03
Outside					3.121E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	572.9	475.3	6.90E-02	9.000E-04	9.415E+03
Outside					3.118E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	582.3	483.0	6.90E-02	9.000E-04	9.465E+03
Outside					3.110E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	591.2	490.4	6.90E-02	9.000E-04	9.509E+03
Outside					3.100E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	599.7	497.4	6.90E-02	9.000E-04	9.548E+03
Outside					3.089E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	607.8	504.0	6.90E-02	9.000E-04	9.583E+03
Outside					3.079E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	615.5	510.2	6.90E-02	9.000E-04	9.613E+03
Outside					3.071E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	622.8	516.2	6.90E-02	9.000E-04	9.639E+03
Outside					3.063E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	629.7	521.8	6.90E-02	9.000E-04	9.663E+03
Outside					3.055E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	636.3	527.1	6.90E-02	9.000E-04	9.684E+03
Outside					3.049E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	643.0	547.7	6.90E-02	9.000E-04	9.702E+03
Outside					3.046E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	649.0	552.8	6.90E-02	9.000E-04	9.721E+03
Outside					3.039E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	654.6	557.5	6.90E-02	9.000E-04	9.736E+03
Outside					3.033E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	660.0	562.0	6.90E-02	9.000E-04	9.749E+03
Outside					3.029E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	665.0	566.2	6.90E-02	9.000E-04	9.761E+03
Outside					3.025E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	669.8	570.2	6.89E-02	9.000E-04	9.772E+03
Outside					3.021E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	674.3	573.9	6.89E-02	9.000E-04	9.781E+03
Outside					3.019E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	678.6	577.3	6.88E-02	9.000E-04	9.790E+03
Outside					3.016E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	682.7	580.6	6.88E-02	9.000E-04	9.798E+03
Outside					3.013E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	686.5	583.7	6.87E-02	9.000E-04	9.806E+03
Outside					3.011E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	690.2	586.7	6.87E-02	9.000E-04	9.812E+03
Outside					3.009E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	693.6	589.5	6.86E-02	9.000E-04	9.818E+03
Outside					3.007E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	696.9	592.1	6.86E-02	9.000E-04	9.824E+03
Outside					3.005E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	700.0	594.6	6.85E-02	9.000E-04	9.828E+03
Outside					3.003E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	702.9	596.9	6.85E-02	9.000E-04	9.833E+03
Outside					3.002E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	705.7	599.2	6.85E-02	9.000E-04	9.837E+03
Outside					3.000E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	708.3	601.3	6.85E-02	9.000E-04	9.841E+03
Outside					2.999E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	710.8	603.3	6.84E-02	9.000E-04	9.844E+03
Outside					2.998E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	713.1	605.2	6.84E-02	9.000E-04	9.847E+03
Outside					2.997E+04

Result for ventilation opening 375mm high, 31.25mm wide

```
**      CFAST  Version   2.0.1  Run  2/27/96          **
**                                                    **
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** National Institute of Standards and Technology     **
**             Gaithersburg, MD  20899                **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	1.300E-03	5.480E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	603.6	395.9	6.14E-02	1.300E-03	2.215E+04
Outside					2.138E+04

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	636.0	422.9	6.12E-02	1.300E-03	2.214E+04
Outside					3.156E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	669.3	447.5	6.11E-02	1.300E-03	2.232E+04
Outside					3.318E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	701.2	492.5	6.07E-02	1.300E-03	2.245E+04
Outside					3.320E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	730.6	512.5	6.04E-02	1.300E-03	2.255E+04
Outside					3.297E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	757.7	530.3	6.02E-02	1.300E-03	2.261E+04
Outside					3.278E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	782.9	546.9	6.01E-02	1.300E-03	2.266E+04
Outside					3.264E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	806.1	563.7	6.02E-02	1.300E-03	2.268E+04
Outside					3.253E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	827.5	578.9	6.03E-02	1.300E-03	2.268E+04
Outside					3.246E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	847.3	592.8	6.05E-02	1.300E-03	2.268E+04
Outside					3.242E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	865.5	605.5	6.06E-02	1.300E-03	2.267E+04
Outside					3.239E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	882.5	617.3	6.06E-02	1.300E-03	2.265E+04
Outside					3.237E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	898.1	628.1	6.07E-02	1.300E-03	2.264E+04
Outside					3.236E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	912.6	638.1	6.08E-02	1.300E-03	2.262E+04
Outside					3.236E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	926.0	647.4	6.09E-02	1.300E-03	2.260E+04
Outside					3.236E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	938.5	656.0	6.10E-02	1.300E-03	2.258E+04
Outside					3.236E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	950.1	664.0	6.10E-02	1.300E-03	2.256E+04
Outside					3.237E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	960.9	671.5	6.11E-02	1.300E-03	2.254E+04
Outside					3.237E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	970.9	678.4	6.11E-02	1.300E-03	2.252E+04
Outside					3.238E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	980.2	684.9	6.12E-02	1.300E-03	2.250E+04
Outside					3.239E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	988.8	690.9	6.12E-02	1.300E-03	2.248E+04
Outside					3.240E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	996.9	696.5	6.13E-02	1.300E-03	2.247E+04
Outside					3.241E+04

Result for ventilation opening 250mm high, 125mm wide

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1004.	701.8	6.13E-02	1.300E-03	2.245E+04
Outside					3.242E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1011.	706.7	6.13E-02	1.300E-03	2.243E+04
Outside					3.243E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1018.	711.2	6.14E-02	1.300E-03	2.242E+04
Outside					3.244E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1024.	715.5	6.14E-02	1.300E-03	2.240E+04
Outside					3.245E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1030.	719.4	6.14E-02	1.300E-03	2.239E+04
Outside					3.246E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1035.	723.1	6.15E-02	1.300E-03	2.238E+04
Outside					3.247E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1040.	726.6	6.15E-02	1.300E-03	2.237E+04
Outside					3.247E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1044.	729.8	6.15E-02	1.300E-03	2.236E+04
Outside					3.248E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1049.	732.8	6.15E-02	1.300E-03	2.235E+04
Outside					3.249E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1052.	735.6	6.16E-02	1.300E-03	2.234E+04
Outside					3.250E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1056.	738.2	6.16E-02	1.300E-03	2.233E+04
Outside					3.250E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1060.	740.6	6.16E-02	1.300E-03	2.232E+04
Outside					3.251E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1063.	742.8	6.16E-02	1.300E-03	2.231E+04
Outside					3.252E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	1066.	745.0	6.16E-02	1.300E-03	2.230E+04
Outside					3.252E+04

Result for ventilation opening 250mm high, 125mm wide

Result for ventilation opening 250mm high, 62.5mm wide

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**      CFAST  Version   2.0.1  Run  2/27/96       **
**                                                 **
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** National  Institute of Standards and Technology **
**              Gaithersburg, MD  20899            **
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Time = 0.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	293.0	293.0	0.98	7.000E-04	3.030E+04
Outside					0.000

Time = 150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	531.4	405.3	6.20E-02	7.000E-04	1.241E+04
Outside					3.382E+03

Time = 300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	538.4	419.1	6.12E-02	7.000E-04	9.241E+03
Outside					1.306E+04

Time = 450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	531.9	420.0	6.19E-02	7.000E-04	1.070E+04
Outside					1.570E+04

Time = 600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	544.3	429.7	6.19E-02	7.000E-04	1.067E+04
Outside					1.818E+04

Time = 750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	558.2	440.4	6.18E-02	7.000E-04	1.076E+04
Outside					1.934E+04

Time = 900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	571.7	451.0	6.17E-02	7.000E-04	1.085E+04
Outside					1.980E+04

Time = 1050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	584.6	461.3	6.16E-02	7.000E-04	1.093E+04
Outside					1.993E+04

Time = 1200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	596.9	471.0	6.16E-02	7.000E-04	1.100E+04
Outside					1.991E+04

Time = 1350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	608.5	480.2	6.15E-02	7.000E-04	1.105E+04
Outside					1.983E+04

Time = 1500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	619.6	488.8	6.15E-02	7.000E-04	1.110E+04
Outside					1.973E+04

Time = 1650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	630.0	496.9	6.15E-02	7.000E-04	1.115E+04
Outside					1.964E+04

Time = 1800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	639.9	504.5	6.14E-02	7.000E-04	1.118E+04
Outside					1.956E+04

Time = 1950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	649.3	511.7	6.14E-02	7.000E-04	1.121E+04
Outside					1.948E+04

Time = 2100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	658.2	518.4	6.14E-02	7.000E-04	1.124E+04
Outside					1.941E+04

Time = 2250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	666.7	524.7	6.14E-02	7.000E-04	1.126E+04
Outside					1.936E+04

Time = 2400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	674.7	530.5	6.13E-02	7.000E-04	1.128E+04
Outside					1.931E+04

Time = 2550.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	682.2	536.0	6.12E-02	7.000E-04	1.130E+04
Outside					1.927E+04

Time = 2700.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	689.4	541.1	6.11E-02	7.000E-04	1.132E+04
Outside					1.923E+04

Time = 2850.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	696.2	546.0	6.10E-02	7.000E-04	1.133E+04
Outside					1.920E+04

Time = 3000.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	702.6	550.5	6.10E-02	7.000E-04	1.134E+04
Outside					1.916E+04

Time = 3150.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	708.7	554.8	6.09E-02	7.000E-04	1.135E+04
Outside					1.914E+04

Time = 3300.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	714.4	558.9	6.09E-02	7.000E-04	1.136E+04
Outside					1.911E+04

Time = 3450.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	719.8	562.7	6.08E-02	7.000E-04	1.137E+04
Outside					1.909E+04

Time = 3600.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	725.0	566.3	6.08E-02	7.000E-04	1.138E+04
Outside					1.907E+04

Time = 3750.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	729.8	569.7	6.07E-02	7.000E-04	1.138E+04
Outside					1.905E+04

Time = 3900.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	734.4	572.9	6.07E-02	7.000E-04	1.139E+04
Outside					1.904E+04

Time = 4050.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	738.7	575.9	6.06E-02	7.000E-04	1.139E+04
Outside					1.902E+04

Time = 4200.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	742.8	578.8	6.06E-02	7.000E-04	1.140E+04
Outside					1.901E+04

Time = 4350.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	746.7	581.5	6.06E-02	7.000E-04	1.140E+04
Outside					1.900E+04

Time = 4500.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	750.3	584.0	6.06E-02	7.000E-04	1.141E+04
Outside					1.899E+04

Time = 4650.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	753.8	586.4	6.05E-02	7.000E-04	1.141E+04
Outside					1.898E+04

Time = 4800.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	757.0	588.6	6.05E-02	7.000E-04	1.141E+04
Outside					1.897E+04

Time = 4950.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	760.1	590.8	6.05E-02	7.000E-04	1.141E+04
Outside					1.896E+04

Time = 5100.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	763.0	592.8	6.05E-02	7.000E-04	1.142E+04
Outside					1.895E+04

Time = 5250.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	765.8	594.7	6.05E-02	7.000E-04	1.142E+04
Outside					1.895E+04

Time = 5400.0 seconds.

Compartment	Upper Temp. (K)	Lower Temp. (K)	Inter. Height (m)	Pyrol Rate (kg/s)	Fire Size (W)
1	768.4	596.5	6.04E-02	7.000E-04	1.142E+04
Outside					1.894E+04

Result for ventilation opening 250mm high, 62.5mm wide